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The Wheat Bunt Problem in Oregon

By
D. E. STEPHENS
and
H. M. WOOLMAN

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RECOMMENDATIONS

Farmers of Oregon lose thousands of dollars annually from the treatment of seed for bunt because of seed killed or injured by treatment and the consequent thin stands of wheat. As shown in this bulletin, these losses may be reduced to a minimum by:

(1) Sowing clean, plump seed which has been fanned and all foreign matter, smut balls, and most of the cracked and injured kernels removed.

(2) Treating the seed by the bluestone-lime method. Use 1 pound of bluestone to 5 to 10 gallons of water, dip 5 minutes, drain 15 minutes, and dip in milk of lime (1 pound of lime to 10 gallons of water). The stronger solution is advisable only when seed is sown in bunt-infested soil. Always wash bluestone-treated seed in lime water.

(3) Treating seed with a formaldehyde solution of 1 pint of commercial formaldehyde to 40 to 45 gallons of water. Dip 3 to 5 minutes, drain, and plant within 24 hours in soil sufficiently moist for prompt growth. For sowing in dry soil, or if treated seed is to be stored for any period of time, the bluestone-lime method is preferable. Good results with formaldehyde-treated seed can be secured by treating the seed one day and sowing it the next. Read pages 25 to 32.

Several highly bunt-resistant wheats which can be safely sown without seed treatment have been discovered at the Sherman County Branch Experiment Station. See pages 37 to 42.

The Wheat Bunt Problem in Oregon*

By D. E. STEPHENS and H. M. WOOLMAN

I. EFFECT OF CHEMICAL SEED TREATMENT ON THE CONTROL OF BUNT AND ON SEED GERMINATION

Bunt, or the stinking smut of wheat, has undoubtedly been the cause of a greater aggregate loss to the world than any other crop pest. Rusts, Hessian fly, chinch bugs, and other enemies have from time to time caused immense losses, but the ravages of each of these have been somewhat restricted in area and to some extent sporadic in character, while the bunt has steadily taken its toll in all localities where wheat has been grown throughout the centuries that this cereal has been the world's principal bread crop. The losses due to it fall not alone on the wheat grower, but extend to all who eat bread. In addition to the direct loss in yield, there are the indirect losses due to the befouling of the threshed grain, the expense of treating the seed, and the actual loss of seed due to the effect of the fungicide on the viability of the grain.

WHAT CAUSES SMUT?

The cause of the disease is a microscopic fungous plant which may belong either to the species *Tilletia tritici* or to the species *Tilletia levis*. The two cannot be distinguished by the ordinary observer and can only be identified with certainty by the use of the microscope. The so-called bunt ball or button, which appears where the grain of wheat should be, is composed of about four million spores or reproductive bodies analogous in their functions to the seed of a flowering plant. When kept dry, these spores retain vitality for several years. Spores twelve years old have been found to germinate. In moist soil, they germinate in from four to eight days, the exact time being governed by the soil temperature and degree of soil moisture. The eventual result of their germination is the production of an infection thread which, coming in contact with the underground parts of a young wheat plant, may, by some means not fully understood, bore its way into the plant tissues. If it finds the host plant congenial, that is to

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* This bulletin is a progress report of cooperative experiments that have been conducted in Oregon by the Oregon Agricultural College Experiment Station and the United States Department of Agriculture relating to the wheat bunt problem. The work reported herein includes methods of seed treatment, and the search for and production of wheat varieties immune or highly resistant to the disease. During the course of the investigations, a number of different people have assisted in the work and in various places in the text reference is made to the assistance rendered by these people. All pathological work has been under the direct supervision of Dr. H. B. Humphrey, Patholigist in charge of Cereal Diseases, United States Department of Agriculture, and Prof. H. P. Barss, Pathologist, Oregon Agricultural College Experiment Station. The wheat breeding work has been supervised by Dr. C. R. Ball, Cerealist, United States Department of Agriculture; J. Allen Clark, Agronomist in charge of Western Wheat Improvement, United States Department of Agriculture; and George R. Hyslop, Farm Crops Specialist, Oregon Agricultural College Experiment Station.

say, if it is a susceptible variety of wheat, it proceeds to make its way to the growing point, the young head, where it will persist and spread as the head grows until the time when the wheat kernel should begin to form. It then assumes entire control of the growth of the kernel, generally preventing the fertilization of the ovary by killing the stamens, or male organs of the plant. It absorbs all the food elements which the wheat plant ordinarily provides for seed formation, converting the food to its own use, the formation of smut spores.

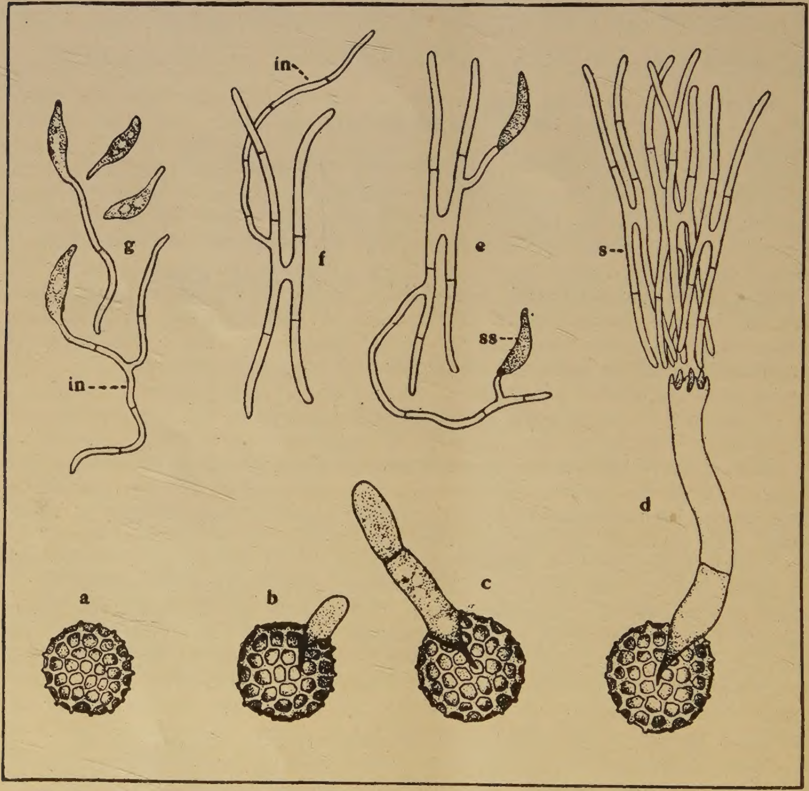

Fig. 1. Various stages in the germination of spores of stinking smut, *Tilletia tritici*. *a*, Spore surface showing characteristic reticulate ridges; *b*, spore in early stage of germination with young promycelium protruding from the ruptured spore wall; *c*, a later stage in the formation of the promycelium; *d*, mature promycelium with a tuft of H-shaped sporidia, *s*, borne in its summit; *e*, a separated sporidium which has produced secondary sporidia, *ss*; *f*, a separated sporidium which has given rise directly to an infection thread, *in*; *g*, several secondary sporidia which have started to germinate or have produced infection threads. (From Wash. Exp Sta. Bul. 126.)

METHODS OF DISTRIBUTION

In the threshing process, many bunt or smut balls become broken and a part of the spores become so persistently attached to the grain to which they adhere that no mechanical method of cleaning will remove them without destroying the viability of the grain. The spores present on the seed

will cause a bunted crop if sown without chemical treatment. A large part of the spores, however, are blown from the thresher and scattered broadcast for miles. Where these settle on summer-fallowed ground already prepared for seeding, they are a more serious menace than the seed-borne spores, as no treatment will prevent infection from them if the crop is sown soon after the first fall rain, as it usually is when summer-fallowing is practiced. The spores begin to germinate as soon as the soil becomes moist, and will be in a condition to infect the young wheat plants for at least a month thereafter. The infection can take place in the young plant anywhere between the seed and the surface of the soil.

Since the time when fairly satisfactory methods of seed treatment were worked out, from twenty to thirty years ago, the central and eastern parts of the United States have had but small losses from bunt except where the growers neglected to treat their seed. In the Pacific Northwest, however, the wheat growers have continued to suffer great losses notwithstanding the fact that seed treatment was universal and usually thorough. Up to a few years ago this state of affairs was a mystery. The explanation was discovered at the Washington Agricultural Experiment Station at Pullman, between the years 1913 and 1917.*

It was found that bunt prevalence in the Pacific Northwest was inseparably connected with the summer-fallow system of farming. It was also found that in certain years more than forty thousand bunt spores per square inch settled on the fields in the vicinity of Pullman, Washington, during the threshing season, and that in certain cases as high as 60 percent of bunt appeared in the crops due to these wind-disseminated spores alone. It is true that in Oregon this annual spore fall is much less than in the Palouse country of southeastern Washington and northern Idaho, but it is sufficient in some localities to cause considerable loss.

Wind Dissemination of Bunt Spores. During the harvesting and threshing season of 1918, an investigation was undertaken to determine the extent of bunt-spore fall in Oregon.

Spore traps were installed at several points in Eastern Oregon and placed under the care of local people.† After threshing had been finished, the contents of these traps were collected and counted by the junior writer. Table I shows the location of traps and number of spores falling per square inch.

On August 6, Messrs. Bell and Kearns collected leaves from trees at intervals along the road from Pendleton to La Grande. The leaves were examined and the spores adhering to them estimated by Miss Jessie P. Rose at Corvallis. Spores were found on them all, the number decreasing in inverse ratio to the distance from Pendleton. The road crosses the Blue Mountains at an elevation of about 4000 feet and spores were found on the top. Another collection was made by the same persons on the road from Elgin in the Grande Ronde Valley to Walla Walla, Washington; spores were found on all collections, but they were comparatively few in number.

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*Heald, F. D. and Woolman, H. M. 1915, Bunt or Stinking Smut of Wheat. Wash. Agr. Exp. Sta. Bul. 126, p. 24, fig. 5.

†Assistance in collecting bunt spores was rendered by the following persons: Harry Key and C. C. Calkins, Moro; J. H. Padburg, Heppner; Geo. White, Lexington; Bernal Hug, Elgin; Robt. Withycombe, Union; Blanch Strode, Mikkalo; Rose Anderson, Condon; Dr. Campbell, Cold Springs; Mr. Coppeck, Athena.

TABLE I. NUMBER OF BUNT SPORES TO THE SQUARE INCH COLLECTED AT SEVERAL LOCALITIES IN OREGON BETWEEN JULY 8, AND SEPTEMBER 24, 1918

Date	Locality	Total number of spores per sq. in. during season
August 10 to August 31	Moro	77
August 31 to September 8	Moro	216①
August 22 to September 10	Moro	75②
August 22 to September 13	Moro	30
August 1 to August 24	Heppner	152
August 1 to August 27	Lexington	73
August 5 to September 24	Elgin	560
August 7 to October 2	Union	190
July 17 to September 16	Mikkalo	2500③
July 17 to September 16	Condon	122
July 17 to August 27	Pilot Rock	1005
July 8 to September 6	Cold Springs	1570
July 8 to August 18	Athena	4466

① Stacking straw close to trap during this period.
② In bean field. Wheat field 20 rods on east and ¾ mile on southwest.
③ Along side of road and near elevator and railroad sidings. The number collected here is probably much more than would have been caught in the neighboring fields.

An observation that clearly shows the great distance that these spores may be transported by the wind was made by the junior author at the town of Haines in the North Powder Valley. Cottonwood leaves collected here on August 5 had adhering to them from 200 to 500 spores to the square inch of surface. At the time the leaves were collected the nearest possible point of origin was the wheat region west of the Blue Mountains around Pendleton, where harvesting had been in operation since about July 4. These spores had evidently been picked up by the wind at an elevation of 1000 to 1500 feet, carried 100 miles to the east, over the Blue Mountains 4000 to 5000 feet high, and finally deposited at an elevation of 3300 feet, the altitude of Haines.

REMEDIES

The results of the investigation above referred to made it evident that the wheat bunt pest in the Pacific Northwest could be controlled only by an entire change in the system of farming or by the production of varieties of wheat immune or highly resistant to the disease. Seeding before the threshing season and replowing the summer fallow after, thus burying the spores below the seed bed, or very late seeding are available remedies under certain conditions; but for obvious reasons all are inapplicable as general methods. Soil treatment for the infection would be impracticable on account of the expense. The Experiment Station workers of Moro and Corvallis and the cooperating agents of the United States Department of Agriculture were therefore convinced that the permanent solution of the problem could only be reached through the production of resistant varieties. The principal part of their work on this problem for the last few years has been directed to this end and it is now felt that it is only a question of time when all the susceptible varieties of wheat now grown in Oregon can be replaced by immune or highly resistant ones having all other desirable qualities. In fact, there are now

in the experimental plots about twenty varieties of several different types ranging from hard red to soft white, any of which could be safely sown without treatment. Some of these immune varieties are certainly unsuitable for commercial growing in Oregon but are of unquestioned value as parents for new hybrid varieties. Even if there were discovered and developed from among these immune and resistant wheats, however, varieties that would be entirely satisfactory for each of the different types of soil and climatic conditions of Oregon, several years would have to elapse before they could be fully tested and increased sufficiently to supply the demand. It is likely that further crosses will have to be made before the ideal types of wheat are obtained. Since in the meantime seed treatment must continue, search for improved methods of treatment has not been neglected.

GEOGRAPHIC DISTRIBUTION AND COMPARATIVE VIRULENCE OF *TILLETIA TRITICI* AND *TILLETIA LEVIS*, THE ORGANISMS CAUSING BUNT

East of the Rocky Mountains *T. levis* is the species generally found, though in some localities both are found occasionally. Both are frequently found in Michigan. West of the Rockies, *T. tritici* is by far the more prevalent. According to Professor W. W. Mackie, of the University of California, it is practically the only species found in California. The two occur in Western Oregon, and in the Willamette Valley in particular, where they are about equally abundant. In the wheat belt of Eastern Oregon and Washington and Northern Idaho, or what is generally called the Inland Empire, *T. levis* has not been found in the field. It does, however, occur in Southern Idaho, notably around Pocatello, where in 1918 it was found by the junior writer in wheat stored in warehouses.

Why *T. levis* has not spread from Western to Eastern Oregon is a matter for conjecture. It has been suggested that the two forms have special soil and climatic adaptations. Experiments in Oregon have furnished little, if any, support for this theory.

To determine the relative virulence of *T. tritici* and *T. levis* under different soil and climatic conditions, lots of twenty-one varities of wheat were first treated with formaldehyde, dried and divided into two portions, one of which was heavily infested with spores of *T. tritici* and the other with *T. levis*. These lots were further divided and planted in the fall of 1918 at Corvallis, Moro, Hermiston, Union, and Medford. Unfortunate conditions at all these places except at Moro prevented the obtaining of complete records from the resulting crop. Reliable records for nine varieties were obtained both at Corvallis and Moro; viz., Pacific Bluestem, Marquis, Jones Fife, Little Club, Banner Berkeley, Unknown, Red Rock, Alberta Red, and Turkey No. 889.

Reliable records for the following six varieties were obtained at Hermiston: Jones Fife, Banner Berkeley, Unknown, Red Rock, Alberta Red, and Turkey No. 889. Reliable records were also secured at Medford for Fortyfold, Turkey (Washington No. 326), and four varieties of Little Club and Fortyfold hybrids produced by Superintendent Withycombe of the Eastern Oregon Branch Experiment Station. No records of these six were obtained except at Medford and Moro.

The average results are given in Table II.

TABLE II. PERCENTAGE OF SMUTTED HEADS FOUND IN WHEAT VARIETIES SOWN IN THE FALL OF 1918 WITH SEED INOCULATED WITH SPORES OF *T. TRITICI* AND *T. LEVIS* AT CORVALLIS, MORO, AND HERMISTON, OREGON

Location	Number of varieties	Percentage of bunted heads	
		T. triciti	*T. levis*
Corvallis	10	44.1	57.2
Moro	20	40.0	26.3
Hermiston	12	42.1	40.5
Average		42.0	31.0

In the fall of 1919 the seed of eight varieties was prepared in the same manner and planted at Corvallis, Moro, Hermiston, Union, and Astoria. The results are given in Table III.

TABLE III. PERCENTAGE OF BUNTED HEADS IN EIGHT WHEAT VARIETIES SOWN AT FIVE PLACES IN OREGON IN THE FALL OF 1919, WITH SEED INOCULATED WITH SPORES OF *T. TRITICI* AND *T. LEVIS*

Variety	Percentage of bunted heads at:									
	Corvallis		Moro		Hermiston		Union		Astoria	
	T. tritici	T. levis	T. tritici	T. levis	T. tritici	T. levis	T. tritici	T. levis	T. tritici	T. levis
Hybrid 143	70.5	78.7	53.1	43.0	68.2	65.8	10.5	23.7	90.1	37.0
Fortyfold	42.5	60.4	67.9	34.9	13.0	38.0	①	①	48.3	40.4
Turkey No. 889	1.1	6.4	6.2	6.9	2.7	0.0	7.5	1.8	0.0	2.1
American Banner	29.4	27.7	52.6	37.7	34.1	22.9	20.0	24.9	8.6	5.7
Fulcaster	3.8	3.8	9.4	8.0	6.2	2.9	15.4	3.3	5.5	5.5
Alaska x Fife	14.0	16.1	1.2	0.7	0.0	0.0	17.2	0.8	5.2	6.9
Turkey (Wn. No. 326)	19.6	21.6	11.1	4.6	4.0	2.8	1.4	1.9	33.7	22.5
Florence	7.0	10.0	6.0	4.0	10.0	10.5	0.0	1.8	12.8	0.0
Average	23.5	28.1	22.2	17.8	17.3	17.9	10.3	8.3	25.5	15.0

①No plants.

In 1919 plantings were made at Corvallis, Moro, Hermiston, Union, and Astoria to test the comparative virulence of spores of both species, (a) produced under the humid conditions of Corvallis and (b) produced under the semi-arid conditions of Moro. The spores of either species showed practically equal virulence whether produced at Corvallis or at Moro. A planting was made at Corvallis of seed infested with a mixture of both kinds of spores. *T. tritici* heads predominated in the resulting crop.

In examination of this crop, the junior writer frequently found heads of both species of bunt in the same plant; in one instance *T. tritici* and *T. levis* were found in the same head.

These results certainly do not indicate that the failure of *T. levis* to invade the fields of the Inland Empire can be attributed to uncongenial soil or climatic conditions.

In the opinion of the authors, it is not necessary to assume special soil and climatic adaption to account for the non-spread of *T. levis* from the Willamette Valley to Eastern Oregon for two reasons. (1) The Cascade Mountains with their humidity probably form an effectual barrier to wind distribution. It is also true that *T. levis* does not pulverize as readily as

T. tritici but tends to break up into comparatively large aggregates in threshing and consequently inclines to settle near the thresher. (2) As different types of wheat are grown in Eastern and Western Oregon, the shipping of seed wheat from the Willamette Valley to east of the Cascades is probably infrequent, and when such shipments do occur, the seed almost certainly would be treated before planting, thus preventing the introduction of *T. levis* by seed-borne spores.

EFFECT OF SEED TREATMENT ON THE GERMINATION OF WHEAT AND CONTROL OF STINKING SMUT

In the autumn of 1912, observations made at the Sherman County Branch Station and elsewhere indicated that treating seed wheat for smut with a formaldehyde solution was responsible in many instances for thin stands of winter wheat.

Results in 1913. In order to determine the effect of the formaldehyde treatment on securing stands of winter wheat, in the fall of 1913 Turkey winter wheat was sown at Moro with a single-disk drill on August 26, in duplicate twentieth-acre plots, two inches and four inches deep. The strength of solution used was 1 pint of formaldehyde to 48 gallons of water, with a five-minute soak in the solution. Untreated seed also was sown in check plots. On November 5 careful stand counts were made on each plot, with the following results:

Shallow sowing, treated	83,000 plants to the acre
Shallow sowing, not treated	120,000 plants to the acre
Deep sowing, treated	37,000 plants to the acre
Deep sowing, not treated	84,000 plants to the acre

The experiment was repeated in duplicate plots on September 9 with a double-disk drill, with the following results:

Shallow sowing, treated	104,000 plants to the acre
Shallow sowing, not treated	140,000 plants to the acre
Deep sowing, treated	62,000 plants to the acre
Deep sowing, not treated	120,000 plants to the acre

In each instance the seed receiving no treatment produced considerably thicker stands than the seed treated with formaldehyde.

Results in 1914. In the fall of 1914, Turkey wheat was treated with bluestone (copper sulfate) and with formaldehyde. A careful germination test between blotters gave the following results:

	Percent germinated
Water soaked, 10 minutes	94
No treatment	92
Bluestone, 1 pound to 5 gallons, soaked 5 minutes	11
Formaldehyde, 1 pint to 48 gallons, soaked 5 minutes	28

Results in 1915. In the fall and winter of 1915, sixteen germination tests were made in the laboratory with wheat, oats, and barley treated with formaldehyde and with bluestone. Table IV gives the results obtained.

TABLE IV. PERCENTAGE OF GERMINATION, WHEAT, OATS, AND BARLEY, TREATED AND UNTREATED

(a) *Percentage of germination on different dates of Turkey winter wheat not treated and treated with formaldehyde and bluestone on November 10, 1915, and placed in germinators the same day.*

Date	Treatment					
	Water soaked 10 min.	Formal. 1 to 48 10 min.	Formal. 1 to 40 10 min.	Formal.① 1 to 40 10 min. washed	Bluestone 1 to 5 gal. 10 min.	Bluestone 1 to 5 gal. 10 min. washed
	%	%	%	%	%	%
November 17	88	74	67	82	20	33
November 18	92	76	74	85	24	54
November 19	94	83	76	88	29	70
November 20	94	85	80	90	31	73
November 22	97	86	83	92	35	76
November 23	97	87	84	92	38	78
December 29	97	92	95	94	74	95
December 29	97	92	95	94	74	95

(b) *Percentage of germination on different dates of plump and shrunken seed of Turkey wheat treated with formaldehyde 1:48 and soaked ten minutes on December 30 and placed in germinators the same day.*

Date	Plump	Shrunken
	%	%
January 5	90	88
January 7	97	94
January 11	97	96
January 18	97	96

(c) *Percentage of germination on different dates of Sixty Day Oats not treated and treated with formaldehyde and bluestone on November 10, 1915, and put in germinators the same day.*

Date	Treatment			
	Dry—no treatment	Formaldehyde, 1:40 ten min.	Bluestone 1:5 gallons ten min.	Bluestone 1:5 gallons ten min. washed
	%	%	%	%
November 17	28	18	6	49
November 18	33	22	13	49
November 19	51	39	21	51
November 20	62	49	29	52
November 22	79	54	35	57
November 23	80	55	38	57
December 29	88	89	79	89

① In the tables of this bulletin the strength of formaldehyde solutions is expressed in a ratio of pints to gallons, thus: 1 to 40 equals 1 pint to 40 gallons. Bluestone solutions are expressed in a ratio of pounds to gallons, as 1:5 equals 1 pound to 5 gallons.

(d) Percentage of germination on different dates of Sixty Day Oats not treated and treated with formaldehyde and bluestone on November 10, 1915, and put in germinators on December 30, 1915.

Date	Treatment			
	Dry—no treatment	Formaldehyde, 1:40 ten min.	Bluestone 1:5 gallons ten min.	Bluestone 1:5 gallons ten min. washed
	%	%	%	%
January 5	26	39	2	45
January 7	73	67	12	63
Janaury 11	100	77	20	75
January 18	100	80	45	75

(e) Percentage of germination on different dates of Maryland Winter Barley treated with formaldehyde on November 10, 1915, and put in germinators the same day.

Date	Treatment	
	Formaldehyde 1:40.	Formaldehyde 1:20,
	%	%
November 17	80	0
November 18	84	7
November 19	87	44
November 20	88	66
November 22	89	70
November 23	89	71
December 29	89	78

(f) Percentage of germination on different dates of Maryland Winter Barley treated with formaldehyde on November 10, 1915, and put in germinators on December 30, 1915.

Date	Treatment	
	Formaldehyde 1:40, ten min.	Formaldehyde 1:20, ten min.
	%	%
January 7	88	0
January 11	88	0
January 18	88	3

It will be noted that in every instance the viability of the seed was injured by treatment and that the copper sulfate treatment was more injurious. In every instance washing or rinsing the seed in clear water increased the percentage of germination. In some instances the final count did not show any difference in the germination, but it will be noted that in nearly all cases there was delayed germination due to the seed treatment.

Results in 1916. In the fall of 1915, seed of Turkey winter wheat (C. I. 1558) was sown in damp soil on two dates at different depths. The first sowing was made on October 26, and the second sowing on November 5. Four lots of seed were used: (1) treated with formaldehyde, 1 pint to 40 gallons, soaked 10 minutes; (2) copper sulfate, 1 pound to 5 gallons, soaked 10 minutes; (3) no treatment; and (4) seed soaked in clear water for 10 minutes. The seed treated with formaldehyde and copper sulfate was in all cases sown first so there would be no chance for reinfection of the seed. Each lot of seed was sown at three depths, 1 inch, 3 inches, and 5 inches for the early sowing, and at two depths, 1 inch and 3 inches for the later sowing. The seed was not artificially infested with

bunt, and, so far as could be observed, contained very little bunt infestation. Tables V and VI indicate the results obtained in 1916. The percent of

TABLE V. EFFECT OF VARIOUS SEED TREATMENTS AND DEPTHS OF SEEDING ON STAND AND SMUT INFECTION IN TURKEY WINTER WHEAT SOWN OCTOBER 26, 1915, AT MORO, OREGON

Treatment	Depth sown	Percent of stand	Number of smutted heads in one-hundredth acre
	in.	%	
Formaldehyde	1	81	2
Bluestone	1	76	0
No treatment, dry	1	110	14
Soaked in water	1	100	5
Formaldehyde	3	85	1
Bluestone	3	65	1
No treatment, dry	3	124	6
Soaked in water	3	100	4
Formaldehyde	5	88	5
Bluestone	5	61	0
No treatment, dry	5	141	16
Soaked in water	5	100	20
Average, formaldehyde	....	85	2.6
Average, bluestone	....	67	0.3
Average, dry	....	125	12.0
Average, water soaked	....	100	9.6
Average, 1 inch depth	....	92	5.0
Average, 3 inches depth	....	94	3.0
Average, 5 inches depth	....	98	10.2

TABLE VI. EFFECT OF VARIOUS SEED TREATMENTS AND DEPTHS OF SEEDING ON STAND AND ON SMUT INFECTION IN TURKEY WINTER WHEAT SOWN ON NOVEMBER 15, 1915, AT MORO, OREGON

Treatment	Depth sown	Percent of stand	Number of smutted heads in one-hundredth acre
	in.	%	
Formaldehyde	1	88	0
Formaldehyde and washed	1	126	0
Bluestone	1	82	0
Bluestone and washed	1	89	0
No treatment, dry	1	113	4
No treatment, water soaked	1	100	6
Formaldehyde	3	119	0
Formaldehyde and washed	3	99	0
Bluestone	3	86	0
Bluestone and washed	3	104	0
No treatment, dry	3	117	3
No treatment, water soaked	3	100	4
Average, formaldehyde	....	103	0
Average, formaldehyde and washed	....	112	0
Average, bluestone	....	84	0
Average, bluestone washed	....	96	0
Average, no treatment, dry	....	115	3.5
Average, no treatment, water soaked	....	100	5.0
Average, 1 inch depth	....	99	1.6
Average, 3 inches depth	....	104	1.1

stand was obtained by dividing the number of plants per unit area for each treatment by the number of plants obtained from the seed soaked in water only.

These tables bring out the following points:

(1) For both early and late seeding, the thinnest stands were obtained from seed treated with copper sulfate. Washing seed treated with copper sulfate and formaldehyde increased the germination. For the late sowing there was no injury to the seed from the formaldehyde treatment.

(2) The thickest stands were obtained from the dry, untreated seed. This was partly due to the fact that more seeds actually were sown, though the drill was set to sow one-half peck less to the acre than for seed treated or soaked in water. The treated and water-soaked seed was not sown for two days after treating and was fairly dry when sown. It had increased in volume, however. No determinations of the actual increase in volume were made, but from later determinations it is estimated that the treated seed probably increased about 25 percent in volume.

(3) For both dates of sowing, the shallow seedings gave thickest stands.

(4) There was less bunt in the crop grown from seed treated with bluestone. There was more bunt in the earlier sowing. In the late sowing, there was no bunt from formaldehyde- or bluestone-treated seed. There was some bunt present in the wheat sown late and not treated, but not so much as in the early-sown wheat which had not been treated.

Results in 1917. In the fall of 1916, four plots of winter wheat treated with formaldehyde were sown in damp soil at the rate of 5, 6, and 7 pecks to the acre, and four plots of untreated seed were sown at the same rate on the same date. Careful stand notes were taken in the early spring of the number of plants on each plot. The number of heads on each plot was determined just before harvest and the number of bundles on each plot was counted when the grain was cut with the binder.

It will be noted from Table VII that there were practically twice as many plants to the acre on plots where the seed was not treated. A portion of this increase, however, was due to the fact that the untreated seed was sown dry and the rate of seeding, therefore, was thicker. Seed after being treated usually increases in volume from 20 to 30 percent. Allowing 30 percent for increase in volume of the treated seed, there was still a decrease of 18½ percent in the number of plants to the acre on account of the treatment with formaldehyde. In other words, 18½ percent of the seed was killed or at least did not emerge because of a ten-minute soak in a formaldehyde solution of 1 pint to 45 gallons of water. Table VII also brings out the point that the number of heads per unit area from the treated and untreated seed is not in proportion to the number of plants per unit area, the thin stands apparently tillering more. From the 8-peck rate, there were twice as many plants on plots where the seed received no treatment, but there were only 30 percent more heads and approximately 28 percent more bundles.

TABLE VII. YIELD AND OTHER DATA FOR TURKEY WINTER WHEAT SOWN ON DECEMBER 1, 1916, WITH SEED TREATED WITH FORMALDEHYDE, AND SEED NOT TREATED

Plot number	Rate in pecks	Stand				Yield in bushels per acre
		Plants per unit area	Heads per unit area	Culms per unit area	Number of bundles per plot	
1149W, treated	5	128	1190	1300	23	17.3
1147W, not treated	5	264	1216	--------	33	20.0
1149E, treated	6	192	1114	1460	27	20.3
1147E, not treated	6	388	1292	1660	32	20.3
1150W, treated	7	200	1046	1450	30	21.0
1148W, not treated	7	380	1276	1607	38	20.6
1150E, treated	8	232	1114	1590	32	21.6
1148E, not treated	8	464	1452	1890	41	23.7

Results in 1918. A rather elaborate experiment was begun in the fall of 1917 at Moro and Corvallis, under the direction of Mr. C. W. Hungerford, to determine the effect of various seed treatments on securing stands of winter wheat and on controlling bunt. The counting of heads to determine the percentage of smut infection was done by Messrs. Hursh, Meier, and Bell. Mr. Bell also aided in making stand counts.

Nineteen different seed treatments were used on heavily bunted seed of Turkey and White Winter wheats. In addition to these treatments, check plots were sown with smutted and unsmutted seed of each variety that had been water soaked. The plots at Moro consisted of five drill rows, 8 rods long; and every fifth plot was a check plot. Turkey, C. I. 1558, threshed with the Station thresher, and White Winter, grown at Corvallis, were used in the experiment.

Table VIII shows the stand and the percentage of bunt obtained on each plot. The figures in the column "percentage of stand" were obtained by dividing the number of plants per unit area on each plot by the average number of plants per unit area on all check plots of each variety.

Table VIII brings out the following points:

(1) Formaldehyde and copper sulfate so injured the seed that stands obtained were much thinner than where these fungicides were not used. In general, the weaker the solution of the fungicide, the better the stand.

(2) Somewhat better bunt control was obtained from the use of formaldehyde than from the use of bluestone. The 1 to 50 solution of formaldehyde with a soak of ten minutes seemed to be as effective in controlling bunt as the stronger solutions of 1 to 40 and 1 to 20, or the longer periods of soaking.

(3) The Haskell method, besides showing some seed injury to the White Winter variety, did not control the smut in either the White Winter or Turkey varieties. This method consists of spraying the seed with a very strong formaldehyde solution and covering for varying lengths of time. It is not in general use and is not recommended for wheat.

(4) The Cresol method neither injured the seed nor controlled the smut.

TABLE VIII. STAND AND PERCENTAGE OF SMUT IN TURKEY AND WHITE WINTER WHEATS GIVEN VARIOUS TREATMENTS WITH FORMALDEHYDE, BLUESTONE, AND CRESOL, AT MORO, OREGON

Treatments	White Winter		Turkey	
	Percent of stand	Percent of smut	Percent of stand	Percent of smut
Check 1, water soaked, clean seed	----	11	----	3.4
1. Formaldehyde 1 to 20, soak 10 minutes	46	4	31	.2
2. Formaldehyde, 1 to 40, soak 10 minutes	64	1	58	.4
3. Formaldehyde, 1 to 50, soak 10 minutes	69	.6	75	.7
Check 2, smutted seed, water soaked	----	96.0	----	28.0
4. Formaldehyde, 1 to 40, soak 10 minutes, covered 24 hours	65	3.0	43	0.0
5. Formaldehyde, 1 to 40, soak 10 minutes covered 2 hours	81	8.0	71	1.3
6. Formaldehyde, 1 to 40, soak 30 minutes, covered 2 hours	73	6.0	65	0.5
Check 1	----	24.0	----	-------
7. Formaldehyde, 1 to 40, soak 60 minutes covered 2 hours	72	5.0	71	0.7
8. Haskell formula, full strength, 1 pint to 50 bushels, covered 5 hours	53	73.0	93	16.0
9. Haskell formula, half strength, 1 pint to 50 bushels, covered 5 hours	56	54.0	86	17.0
Check 2	----	88.0	----	22.0
10. Haskell formula, half strength, 1 pint to 50 bushels, covered 2 hours	71	67.0	81	12.4
11. Haskell formula, half strength, 1 pint to 50 bushels, covered 5 hours	59	58.0	88	23.0
12. Haskell formula, fifth strength, 1 pint to 50 bushels, covered ½ hour	47	24.0	95	17.5
Check 1	----	29.0	----	11.5
13. Haskell formula, fifth strength, 1 pint to 50 bushels, covered 2 hours	88	52.0	100	17.5
14. Haskell formula, fifth strength, 1 pint to 50 bushels, covered 5 hours	92	72.0	122	17.4
15. Bluestone, 1 to 5+salt, rinsed clear water	68	17.0	67	4.7
Check 2	----	86.0	----	25.0
16. Bluestone, 1 to 5 +salt, not rinsed	51	5.0	42	0.0
17. Bluestone, 1 to 5+salt, rinsed lime water	75	17.0	75	1.1
18. Cresol, 1 to 360	91	87.0	116	36.0
19. Cresol, 1 to 1000	107	86.0	97	21.0

Average number plants, treated, 188; average number plants, not treated, 374; average number heads, treated, 1116; average number of heads, not treated, 1309; average number bundles, treated, 28; average number bundles, not treated, 36.

Average yield, all rates treated, 20.1 bushels per acre; average yield, all rates not treated, 21.1 bushels per acre; average yield, five-peck rate, 18.6 bushels; average yield, six-peck rate, 20.3 bundles; average yield, seven-peck rate, 20.8 bushels; average yield, eight-peck rate, 22.6 bushels.

Results in 1919. In the fall of 1918 Turkey and Fortyfold wheats were sown in one-thirtieth-acre plots, each variety being given twenty-five different treatments with formaldehyde and copper sulfate. Mr. J. C. Bell treated all seed and assisted in the sowing and taking of stand counts. Table IX shows the percentage of stand as compared with check No. 2, the percentage of bunt based on head counts, and the acre yield in bushels obtained from each plot.

The rate of sowing for the different treatments for each variety was ascertained by tying a small bag on the end of two drill tubes while drilling the whole length of the plot (380 feet). From the seed obtained from the two drill tubes, the actual number of pounds and kernels per acre was computed. This information is given in Table IX.

As is shown in Table IX, the average yield obtained from the three check plots, sown with clean, dry, untreated seed, was 27.5 bushels an acre from the Turkey variety, and 18 bushels an acre from the Fortyfold variety. The average yield obtained from all plots sown with formaldehyde-treated seed was 22.3 bushels an acre from the Turkey variety and 14.8 bushels an acre from the Fortyfold variety. The average yield from all plots sown with seed treated with bluestone was 24.3 bushels an acre from the Turkey variety and 15.1 bushels from Fortyfold. The average yield for both bluestone- and formaldehyde-treated seed was 23.3 for Turkey and 15.0 for Fortyfold. In 1919, therefore, there was a reduction in yield of more than 4 bushels an acre for Turkey wheat and of 3 bushels an acre for Fortyfold wheat because of seed treatment. The yield of the plots sown with smutted seed not treated, however, was only 20 bushels an acre for Turkey and 5.5 bushels an acre for Fortyfold, the latter variety containing 68.1 percent of smut as against 19 percent of smut for the Turkey variety.

The results obtained from this test, as shown in Table IX, and the results obtained in 1918, as shown by Table VIII, indicate that from 30 to 40 percent of the seed is so injured by the regular formaldehyde treatment that the plants never emerge and 40 to 50 percent of the seed treated with the usually recommended bluestone formula never comes up. While this item alone is important, it does not tell the whole story. The seed treated with either formaldehyde or bluestone seems to be so reduced in vigor that it does not come up until four or five days later than seed sown with no treatment. This was true for the seed treatment plots sown in the fall of 1917 and in the fall of 1918. Height measurements were taken on November 19, 1918, on 100 plants on each of the check plots, with the following results.

Treatment	Average height in mms. of 100 plants	
	Turkey	Fortyfold
Check 1, no treatment (dry)	53.5	67.3
Check 2, no treatment (wet)	54.5	69.3
Check 3, formaldehyde 1 to 40	51.5	58.0
Check 4, bluestone 1 to 5	44.8	51.0

TABLE IX. PERCENTAGE OF SMUT INFECTION, STAND AND ACRE YIELDS OF TURKEY AND GOLDCOIN (FORTYFOLD) WHEATS AFTER TREATMENT WITH VARIOUS SOLUTIONS AND SOWN AT MORO, OREGON, IN 1919

Method of treatment	Turkey Smut	Turkey Stand Plants	Turkey Stand Heads	Turkey Yield per acre	Fortyfold Smut	Fortyfold Stand Plants	Fortyfold Stand Heads	Fortyfold Yield per acre
	%			bu.	%			bu.
1. Check, clean seed, sown dry	1.3	105	107	27.5	7.3	115	104	18.0
2. Check, smutted seed soaked in water 10 minutes	19.1	100	100	20.0	68.1	100	100	5.5
3. Check, formaldehyde, 1 to 40, soaked 10 minutes	.7	56	95	25.0	5.7	57	84	16.5
4. Check, bluestone, 1 to 5, soaked 5 minutes	2.1	38	86	23.0	9.4	32	71	15.5
5. Formaldehyde, 1 to 20, soaked 10 minutes	.9	38	83	22.0	12.3	33	37	12.0
6. Formaldehyde, 1 to 30, soaked 10 minutes	.3	50	87	22.0	2.1	52	83	11.5
7. Formaldehyde, 1 to 40, soaked 10 minutes, clean seed	.1	65	95	23.5	.7	58	72	15.0
8. Formaldehyde, 1 to 40, soaked 10 minutes, covered 4 hours	.4	62	98	22.0	.2	66	87	15.5
9. Formaldehyde, 1 to 40, soaked 10 minutes, covered 24 hours	.0	55	91	22.5	.2	64	104	15.0
10. Formaldehyde, 1 to 40, covered 4 hours, rinsed water	.0	52	90	19.5	.6	58	99	15.0
11. Formaldehyde, 1 to 40, sown at once	.1	62	90	22.5	.0	70	87	15.5
12. Formaldehyde, 1 to 50	.0	85	100	22.5	.7	86	99	15.0
13. Formaldehyde, 1 to 40, soaked 2 hours, no rinse	.0	58	92	22.0	.0	54	84	14.0
14. Formaldehyde, 1 to 40, soaked 2 hours, rinsed water	.0	52	96	21.5	2.7	60	86	20.5
15. Bluestone, 1 to 1, sprinkle and sow at once	.0	28	81	24.0	1.5	20	77	15.5
16. Bluestone, 1 to 5, soaked 5 minutes, rinsed water	1.2	45	97	24.0	.0	31	67	16.5
17. Bluestone, 1 to 5, soaked 5 minutes, rinsed lime water	.1	41	93	24.5	2.2	36	78	14.5
18. Bluestone, 1 to 5, 1 pound salt, soaked 5 minutes, no rinse	.0	29	95	23.5	.2	18	75	16.5
19. Bluestone, 1 to 10, soaked 5 minutes, no rinse	1.4	41	94	25.0	5.4	38	88	15.5
20. Bluestone, 1 to 10, soaked 1 hour, rinsed lime water	1.0	48	90	23.5	4.0	39	90	14.5
21. Bluestone, 1 to 10, soaked 1 hour, no rinse	1.3	32	82	23.5	5.4	32	72	13.5
22. Bluestone, 1 to 25, soaked 20 minutes, no rinse	1.5	48	94	26.0	4.0	44	91	14.0
23. Formaldehyde, 1 to 40, smut balls remaining	.4	95	109	23.5	......	......	......	......
24. Formaldehyde, 1 to 40, smut balls skimmed	.2	96	114	22.0	......	......	......	......
25. Formaldehyde spray, 0.2 pints to the bushel, covered 4 hours	4.4	48	68	22.5	13.9	42	73	13.0
26. Formaldehyde spray, 0.2 pints to the bushel, covered 24 hours	3.3	42	67	21.5	21.0	33	82	13.5

Rates of sowing as follows:
Dry seed, drill at 3½ pecks. Turkey, 60 pounds or 1,246,500 kernels an acre.
Dry seed, drill at 3½ pecks. Fortyfold, 58 pounds or 1,010,600 kernels an acre.
Treated seed, drill at 4½ pecks. Turkey, 53 pounds or 1,084,860 kernels an acre.
Treated seed, drill at 4½ pecks. Fortyfold, 49 pounds or 815,850 kernels an acre
Sown at once, drill at 4½ pecks. Turkey, 39 pounds or 825,240 kernels an acre.
Sown at once, drill at 4½ pecks. Fortyfold, 34 pounds or 574,980 kernels an acre.

Size of plots, one-thirtieth acre. All checks in triplicate, one series on each end and one in the middle. Single plot of all other treatments.

The figures in the preceding tables do not adequately bring out the real difference in the appearance of the treated and untreated plots. Until quite late in the spring there was a marked difference in the appearance of the treated and untreated plots, the latter being much thicker and taller. Fig. 2 shows a general view of the seed-treatment plots in 1919.

Woolman* found that practically all of the loss of germinative power caused by seed treatment with copper sulfate occurs in consequence of injury to the seed coat of the grain, received in threshing, and that seed

Fig. 2. General view of seed-treatment plots in 1919 showing difference in stands obtained from various seed treatments for smut.
Turkey Fortyfold Turkey Fortyfold
Treated with bluestone, 1 lb. to 10 gallons water, soaked 5 minutes.
No treatment.

threshed by hand was uninjured by ordinary treatment with that fungicide. Hurd† confirmed this conclusion and found also that an after-dip in milk of lime was a preventive of injury only to a partial extent depending upon the nature, extent, and location of the breaks in the seed coat. Seed-coat injury is also a factor affecting the germination loss from formaldehyde treatment but to a less extent.

In order to determine whether farmers in threshing injure the seed as much as the Station thresher, three samples were obtained from the local warehouse of seed threshed by three different combines, two small outfits, and one large Harris combine. These, with two samples of Station seed, were given four different treatments, as outlined in Table X. Each lot was sown in duplicate two-rod rows with the Planet Junior drill, and a germination test made with 100 kernels of each lot. The germination test was made in a room where the temperature ranged from 30° to 45° F. The results of this germination test are given in Table X.

* Woolman, H. M. Stinking smut in wheat, Wash. State Exp. Sta. Bul. 73, pp. 8.

†Hurd, Dr. Annie May. Seed-coat injury and viability of seeds of wheat and barley as factors in susceptibility to moulds and fungicides. Jour. Agr. Research V. 21, No. 2, pp. 100-122, plates 13-23.

TABLE X. RESULTS OF GERMINATION TEST BETWEEN BLOTTERS OF FIVE DIFERENT LOTS OF SEED OF TURKEY WHEAT, GIVEN VARIOUS SEED TREATMENTS AT MORO, OREGON

Treatment	Percentage of germination			
	Good	Weak	Dead	Total
	%	%	%	%
Station seed—				
1. Plump (62 pounds per bushel), water soaked 10 minutes	84	14	2	98
2. Plump (62 pounds per bushel), bluestone soaked 5 minutes	16	22	62	38
3. Plump (62 pounds per bushel), formaldehyde 1 to 20, soaked 10 minutes	38	50	12	88
4. Plump (62 pounds per bushel), formaldehyde 1 to 40, soaked 10 minutes	42	40	18	82
1. Shrunken (55 pounds), water soaked 10 minutes	22	76	2	98
2. Shrunken (55 pounds), bluestone soaked 5 minutes	0	22	78	22
3. Shrunken (55 pounds), formaldehyde 1 to 20, 10 minutes soak	10	50	40	60
4. Shrunken (55 pounds), formaldehyde 1 to 40, 10 minutes soak	16	64	20	80
Barnum's seed; plump, small combine (62 pounds)—				
1. Water soaked 10 minutes	82	12	6	94
2. Bluestone 1 to 5, soaked 5 minutes	10	30	60	40
3. Formaldehyde 1 to 20, soaked 10 minutes	40	42	18	82
4. Formaldehyde 1 to 40, soaked 10 minutes	60	28	12	88
Torey's seed; small combine (60 pounds)—				
1. Water soaked 10 minutes	90	10	0	100
2. Bluestone 1 to 5, soaked 5 minutes	14	44	42	58
3. Formaldehyde 1 to 20, soaked 10 minutes	48	52	0	100
4. Formaldehyde 1 to 40, soaked 10 minutes	62	38	0	100
Powell's seed; large combine (59 pounds)—				
1. Water soaked 10 minutes	92	6	2	98
2. Bluestone 1 to 5, soaked 10 minutes	22	32	46	54
3. Formaldehyde 1 to 20, soaked 10 minutes	44	46	10	90
4. Formaldehyde 1 to 40, soaked 10 minutes	70	28	2	98

It will be seen from Table X that considerable injury was done to all the seed, but that the shrunken seed was injured more than the plump seed. It is probable that a large percentage of the seed showing weak germination would never emerge under field conditions.

Table XI gives the results of a test with Turkey, Kanred, and early Baart wheats threshed by hand and by machine. The Turkey wheat was threshed with the Station thresher and the Early Baart with a small combine.

Table XI shows that much more injury occurred to the machine-threshed seed. The germination test was made in a room where freezing temperatures prevailed at night.

TABLE XI. PERCENTAGE OF GERMINATION OF MACHINE- AND HAND-THRESHED SEED OF TURKEY AND EARLY BAART WHEATS TREATED WITH FORMALDEHYDE, 1 TO 24, SOAKED FIVE MINUTES.

Variety	Manner of threshing	Percentage of germination			
		Good	Weak	Dead	Total
		%	%	%	%
Turkey (plump), not treated	Machine	48	42	10	90
Turkey (plump), 1 to 24	Machine	38	42	20	80
Turkey (shrunken), not treated	Machine	18	38	44	56
Turkey (shrunken), 1 to 24	Machine	12	26	62	38
Kanred (plump), not treated	Hand	94	6	0	100
Kanred (plump), 1 to 24	Hand	86	14	0	100
Baart (shrunken), not treated	Hand	80	20	0	100
Baart (shrunken), 1 to 24	Hand	68	30	2	98
Baart (shrunken), not treated	Machine	28	46	26	74
Baart (shrunken), 1 to 24	Machine	8	62	30	70
Baart (plump), not treated	Hand	72	26	2	98
Baart (plump), 1 to 24	Hand	56	28	16	84

Results in 1921. In the fall of 1921, several tests were made to determine the effect on germination, both in the field and in the laboratory, of different wheat varieties given various seed treatments and sown in dry and damp soil.

On September 26, Turkey winter wheat, which had been threshed with the Station thresher, was given five different treatments and sown in damp soil about 2½ inches deep. On October 11, the percentage of germination was as follows:

	Percentage of germination
1. Formaldehyde, 1:44, soaked 5 minutes	80
2. Formaldehyde, 1:44, soaked 5 minutes, rinsed in clear water	100
3. Bluestone, 1:5, rinsed in lime water	66
4. Bluestone, 1:10, rinsed in lime water	93
5. Bluestone, 1:10, not rinsed	78
6. Dry seed, no treatment	93

On September 30, twenty lots of seed including three varieties—Turkey, Hybrid 128, and Blackhull—were given various treatments as indicated in Table XII. Each lot was germinated between blotters in the laboratory and also sown in duplicate series two inches deep in dry soil containing about 5 percent moisture. One series was watered ten days after planting and the other twenty days after planting. The soil was placed in boxes outdoors, and temperatures considerably below freezing prevailed at several different times between date of planting and making final emergence counts. The results obtained are shown in Table XII.

It will be observed from this table that the percentage of germination between blotters in the laboratory and in soil outdoors varied widely in many instances. The formaldehyde-treated seed gave better germination between blotters than in soil, especially when sown in dry soil and not watered for twenty days after planting. Compared with the formaldehyde-treated seed, the bluestone-treated seed gave better germination when sown in dry soil. This was especially true of the seed that remained in dry soil twenty days before the addition of sufficient moisture to begin germination. Averaging all treatments, 16.5 percent more plants emerged from seed treated with bluestone in the first series and 40.5 percent more

in the second series than from seed treated with formaldehyde. As is shown in previous tables, the reverse usually occurs at Moro when the seed is sown in damp soil soon after treatment, formaldehyde-treated seed generally giving better stands of wheat.

It will also be noted from Table XII that in every instance both in the laboratory and when planted outdoors in soil, the hand-threshed seed gave much better germination than machine-threshed seed, indicating, beyond question, that seed injury frequently is caused by the threshing machine. The Turkey wheat used in the experiment was obtained from a commercial sample threshed with a large combine. Seed of Hybrid 128 and Blackhull was threshed by the Station thresher. In comparing the machine-threshed with the hand-threshed seed of Hybrid 128 and Blackhull, the average percentage of germination in Series 1 was 77 for the hand-threshed seed as against 40 for machine-threshed seed. In Series 2, the average percentage of germination of these varieties for hand-threshed seed was 68 and for machine-threshed seed, 35.

As is indicated in Table XII, some of the seed was thoroughly dried before sowing and some was sown in the dry soil immediately after treatment or when the seed was damp. The results shown in the table do not indicate any special advantage or disadvantage in sowing dry or damp seed in dry soil. The soil used in this experiment was probably drier than it ordinarily would be under usual field conditions. Dry seed is probably to be preferred in farm practice when seed is sown in soil so dry that prompt germination is not likely to occur.

Table XII also shows the effect of seed treatment in delaying germination. In most instances, the untreated seed emerged sooner than the treated seed. In Series 1, sown in dry soil and watered ten days afterwards, the untreated seed and the formaldehyde-treated seed emerged in most instances sooner than the bluestone-treated seed.

Rinsing the formaldehyde-treated seed in clear water significantly increased the percentage of germination. Rinsing after treatment was much more effective in reducing seed injury than soaking the seed before treatment, as advocated by Braun.*

On November 26, seed of Turkey, Hybrid 128, Hybrid 123 and Triplet were given various treatments with bluestone and formaldehyde, as indicated in Table XIII. The seed was germinated in the laboratory between blotters and sown in damp soil outdoors. The results obtained are shown in Table XIII. In this test again there was a significant difference in the germination of seed threshed by hand and that threshed with a machine. In the use of a solution of formaldehyde as strong as 1 lb. to 20 gallons, it will be noted that considerable injury was done to the seed. This injury, however, was to a considerable extent overcome by rinsing the seed after treatment. The clear water, however, was somewhat more effective in reducing injury than the lime water. In several additional tests carried on at Corvallis and Moro with the formaldehyde-treated seed rinsed in clear water and in lime water, the results showed that clear water was just as efficient in reducing injury as the lime water.

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*Braun, Harry. Presoak method of seed treatment. Journal of Agricultural Research, Vol. XIX, p. 363.

TABLE XII. PERCENTAGE OF GERMINATION OF WINTER WHEAT GIVEN VARIOUS SEED TREATMENTS AND GERMINATED IN LABORATORY AND IN SOIL OUTDOORS

Treatment②	Percentage of germination											
	In laboratory			Series 1①					Series 2①			
	Strong	Weak	Dead	10/28	11/8	11/15	11/28	12/26	11/8	11/15	11/28	12/26
	%	%	%	%	%	%	%	%	%	%	%	%
1A. Dry seed, no treatment	89	9	2	43	79	79	79	82	12	52	60	69
1B. Water soaked 10 minutes, sown damp	89	9	2	40	75	76	77	78	4	48	59	81
2A. Formaldehyde, 1 to 44, sown dry	50	42	8	11	35	39	42	43	3	3	6	15
2B. Formaldehyde, 1 to 44, sown damp	50	42	8	10	40	43	43	45	0	5	6	13
3A. Formaldehyde, 1 to 44, washed clear water, sown dry	86	10	4	23	67	70	70	72	14	56	64	65
3B. Presoak 10 minutes clear water, dry 6 hours, treat as 2A	68	29	3	16	54	55	56	64	1	13	21	21
4A. Bluestone, 1 to 5, rinsed lime water, sown dry	78	15	7	12	65	78	78	78	13	43	54	68
4B. Bluestone, 1 to 5, no lime, sown dry	4	30	66	16	49	56	58	63	4	23	38	54
5A. Bluestone, 1 to 5, limed, sown damp	78	15	7	4	12	25	30	40	10	55	68	81
5B. Bluestone, 1 to 10, no lime, sown damp	40	42	18	4	21	33	38	58	8	52	68	72
6A. Bluestone, 1 to 10, limed, sown dry	62	38	0	4	28	58	64	75	13	82	82	83
6B. Copper carbonate, sown dry	85	14	1	1	12	43	57	65	45	62	72	77
7A. Hybrid 128, machine-threshed, formaldehyde, 1 to 44, sown dry	64	31	5	11	14	22	28	28	0	0	0	2
7B. Hybrid 128, hand-threshed, formaldehyde 1 to 44, sown dry	80	18	2	4	12	15	34	52	1	23	39	45
8A. Blackhull, machine-threshed, formaldehyde, 1 to 44, sown dry	54	35	11	7	19	22	22	24	1	4	7	7
8B. Blackhull, hand-threshed, formaldehyde 1 to 44, sown dry	78	22	0	2	39	71	76	76	37	72	72	76
9A. Hybrid 128, hand-threshed, bluestone, 1 to 5, limed, sown dry	72	28	0	5	14	39	70	95	30	99	99	99
9B. Hybrid 128, machine-threshed, bluestone, 1 to 5, limed, sown dry	4	91	5	0	13	37	52	72	50	64	69	72
10A. Blackhull, hand-threshed, bluestone, 1 to 5, limed, sown dry	90	10	0	8	25	79	86	86	0	35	43	52
10B. Blackhull, machine-threshed, bluestone, 1 to 5, limed, sown dry	35	46	19	0	7	22	30	37	8	37	51	58
Average no treatment	89	....	....	....	....	....	78	80	....	....	60	75
Average, all formaldehyde treatments	66	....	....	....	....	....	46	50.5	....	....	27	30.5
Average, all bluestone treatments	55	....	....	....	....	....	56	67	....	....	64	71
Average, copper carbonate treatment	85	....	....	....	....	....	57	65	....	....	72	77
Average, all hand-threshed	80	....	....	....	....	....	....	77	....	....	....	68
Average, all machine-threshed	39	....	....	....	....	....	....	40	....	....	....	35

① Series 1 sown in dry soil on September 30 and watered October 10.
Series 2 sown in dry soil on September 30 and watered October 20.

② A commercial sample of Turkey wheat threshed with a large combine was used for treatments 1A to 6B, inclusive.

TABLE XIII. PERCENTAGE OF GERMINATION BETWEEN BLOTTERS AND IN SOIL OF FOUR WINTER WHEAT VARIETIES, MACHINE- AND HAND-THRESHED, AND TREATED FOR SMUT WITH FORMALDEHYDE AND BLUESTONE.

Treatment	Germination between blotters			Germination in soil①	
	Strong	Weak	Dead	12-17-21	1-21-22
	%	%	%	%	%
1. Turkey, form. 1 to 20, rinsed clear water	94	5	1	19	42
2. Turkey, form. 1 to 20, rinsed lime water	52	30	18	12	48
3. Turkey, not treated, dry seed	76	22	2	6	46
4. Turkey, hand-threshed, form. 1 to 20	50	50	0	38	73
5. Turkey, hand-threshed, $CuSO_4$, 1 to 5, limed	90	10	0	55	67
6. Turkey, machine-threshed, form. 1 to 20	78	18	4	3	17
7. Turkey, machine-threshed, $CuSO_4$, 1 to 20, limed	40	52	8	14	26
8. Hybrid 128, hand-threshed, form. 1 to 20	84	16	0	15	16
9. Hybrid 128, hand-threshed, $CuSO_4$, 1 to 5, limed	94	6	0	17	33
10. Hybrid 128, machine-threshed, form. 1 to 20	34	50	16	5	9
11. Hybrid 128, mach-threshed, $CuSO_4$, 1 to 5, limed	22	74	4	9	16
12. Hybrid 123, hand-threshed, form. 1 to 20	98	2	0	41	29
13. Hybrid 123, hand-threshed, $CuSO_4$, 1 to 5, limed	94	6	0	37	48
14. Hybrid 123, machine-threshed, form. 1 to 20	66	26	8	4	5
15. Hybrid 123, mach-threshed, $CuSO_4$, 1 to 5, limed	60	32	8	8	13
16. Triplet, hand-threshed, form. 1 to 20	82	16	2	16	53
17. Triplet, hand-threshed, $CuSO_4$, 1 to 5, limed	90	10	0	34	53
18. Triplet, machine-threshed, form. 1 to 20	74	26	0	16	33
19. Triplet, machine-threshed, $CuSO_4$, 1 to 5, limed	50	40	10	3	23

①On account of cold weather, complete emergence had not taken place.

WHY SEED IS INJURED BY TREATMENT WITH FUNGICIDES

The failure of seed to germinate after treatment with formaldehyde appears to depend largely on the length of time intervening between treatment and planting, and upon the conditions under which it is kept or stored. In the case of immediate planting, the degree of soil moisture is also an important factor.

Without doubt the factor of greatest importance in causing loss of seed in treating is the injury sustained by the seed coat in threshing. As has been stated, this factor is of more importance in treatment with bluestone than with formaldehyde. The nature of this injury to the seed coat is clearly shown in Fig. 3, *A* and *B*. The apparent difference in size between the uninjured hand-threshed seed and the machine-threshed is due to the fact that the first was untreated while the second had been treated by various methods. It will be noted that there is some difference in the character of the injury in the soft, plump-kerneled White Winter wheat grown at Corvallis and the hard, shrunken, long-kerneled Turkey wheat grown at Moro, in that the injury to the latter is more nearly confined to the seed coat over the germ. It is probable that some varieties are more easily injured than others, but this has not been definitely proved. It is, however, true beyond doubt that grain threshed under very dry conditions is injured more than when the grain is slightly moist or the atmosphere humid.

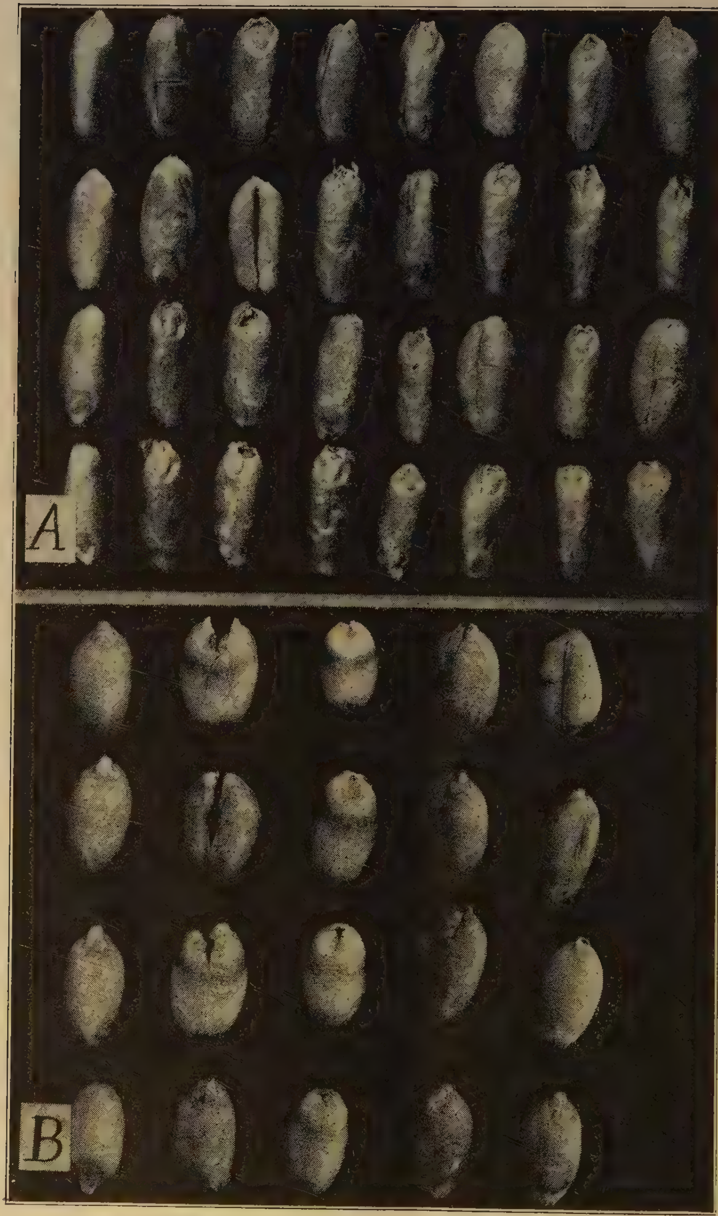

Fig 3. Threshing injury. *A*. Turkey Red from Moro. *B*. White Winter from Corvallis. Hand-threshed on left. Machine-threshed on right.

Falke* found that wheat produced in a dry year was injured more in treating with bluestone than that produced in an ordinary year. He believed that this held good even if the seed coat was unbroken, but the data he presents do not prove this contention.

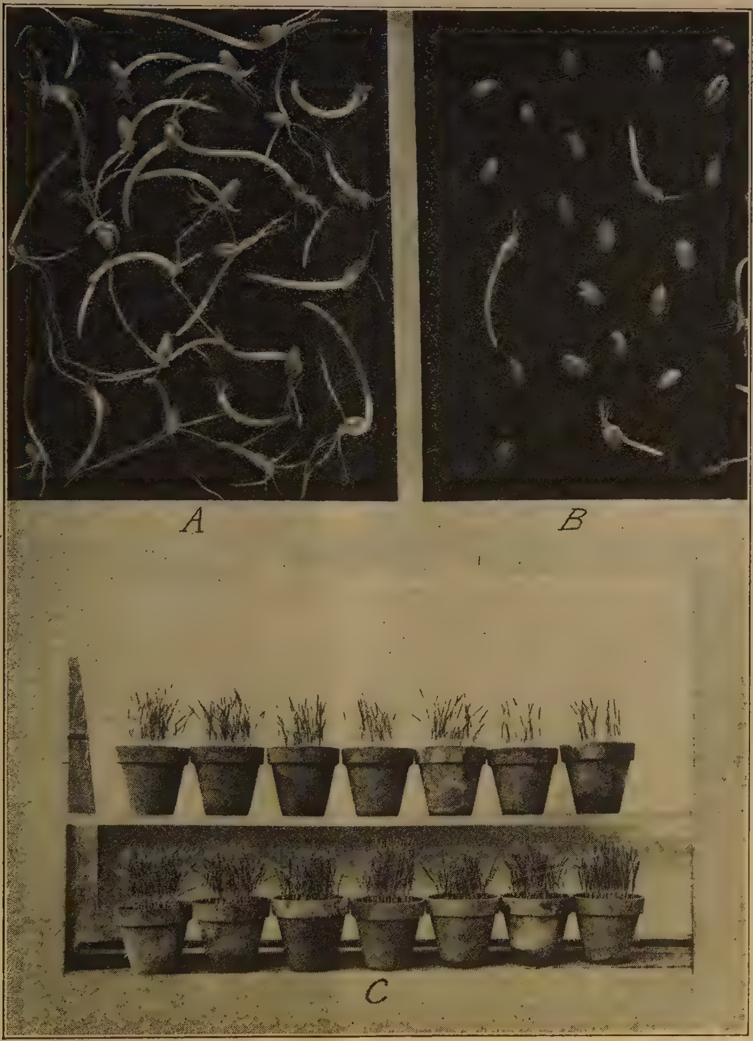

Fig. 4. Hand- and machine-threshed seed, treated with copper sulfate 1 pound to 5 gallons. Explanation in text.

*Falke, Fr. 1905. Beobachtungen uber den Einfiuss der Saatgutbeize auf die Keimfahigkeit des Getreides in trockenen Jahren (1904.) Observations concerning the influence of seed treatment upon the germinative power of cereals in dry years. In Illus. Landw. Ztg., Jahrg, 25 No. 53, p. 479-480, 1905.

Certain interesting facts concerning treatment injury to hand- and machine-threshed seed are shown in Fig. 4. *A* shows 25 grains of Forty-fold wheat selected at random from a lot of hand-threshed seed that had been treated for five minutes with a bluestone solution of 1 pound to 5 gallons of water germinated between moist blotting paper; *B* shows the same except that it was machine-threshed. *C* shows pot cultures of the same seed lots with the same solution as *A* and *B* for varying lengths of

Fig. 5. *A*. Hand-threshed, no treatment. *B*. Machine-threshed, no treatment. *C*. Hand-threshed, treated in 1 to 40 formaldehyde 30 minutes. *D*. Machine-threshed, same treatment as *C*.

time. Upper row was machine-threshed, lower row hand-threshed. Counting from the left, the second lower pot was planted with 25 grains of the same lot as *A*. Second upper from same lot as *B*. Judging from *B*, one would suppose that 80 percent of the grains were dead, but when planted in soil they gave nearly 80 percent of plants. This is unquestionably due to the action of certain chemical substances in the soil that counteract the toxic effects of the bluestone on the grain.

The length of treatment in the pot series is, left to right: 1, no treatment; 2, 5 min.; 3, 10 min.; 4, 30 min.; 5, 1 hour; 6, 5 hours; 7, 10 hours.

In Fig. 5, *A* is hand-threshed, no treatment; *B*, machine-threshed, no treatment; *C*, hand-threshed, 30 minutes in formaldehyde, 1 pint to 40 gallons; and *D*, machine-threshed, same treatment as *C*.

A and *B* show that there is some loss and delayed growth in untreated seed due to threshing injury. Several of the grains shown in *B* would never have emerged if planted under ordinary field conditions. In Fig. 5, *C* and *D* show to some extent the nature of formaldehyde injury. For this short treatment (30 minutes) but little difference between hand- and machine-threshed seed is apparent. One action of formaldehyde on all wheat is the hardening of the seed coat which makes it difficult for the plumule to break through, causing it sometimes to break out at the brush end of the seed. It also causes crooked and distorted plumules which never reach the surface. This explains why blotter germination tests do not fully indicate the actual damage done by formaldehyde. The opposite is true in the case of copper-sulfate treatment, where the stand in the field is generally better than blotter tests indicate. Delayed germination in formaldehyde-treated grain is clearly shown in the figures, as all blotter germinations shown in Figs. 3 and 4 are of the same age.

Considerable light is thrown on the reasons why chemical treatment is injurious to the vitality of the seed, at least in so far as formaldehyde is concerned, by the studies carried on in 1919, 1920 and 1921 by Dr. W. M. Atwood, Plant Physiologist of the Oregon Agricultural College Experiment Station. In the course of work now ready for publication he found: (1) that formaldehyde is able slowly to penetrate the seed coats in aqueous solution, the coats acting as a partly permeable membrane to formaldehyde; (2) that it lowers diastatic enzyme activity; (3) that it checks the respiratory activity of the seed; and (4) that it reduces the catalase content of the seed in proportion to the concentration of the formaldehyde solution used.

These effects all retard important normal functions involved in healthy seed germination, although the actual results are not severe in the case of uninjured seed where the standard dilution of formaldehyde is used and germination is started promptly.

Breaks in the seed coat promote another class of losses not necessarily related to treatment, in that they facilitate the attack of molds and other soil fungi which rob the young plant of the food supply stored in the seed, and upon which it is dependent until it emerges from the soil. The relation of seed treatment to this trouble has not been fully investigated. According to Hurd* treatment with copper sulfate under some circumstances delays the attack of these fungi, but formaldehyde treatment is

* Hurd, Dr. Annie May: Seed-coat injury, etc. Jour. of Agr. Research, Vol. XXI, No. 2, pp. 99-122.

likely to promote the attack. German investigators have expressed the same opinion.

During 1918, 1919, and 1920, an extensive series of tests to determine the relative merits of various seed treatments for the prevention of bunt in relation to loss of germinative power were carried out at Corvallis by Miss Jessie P. Rose, for the Office of Cereal Investigation, in cooperation with the Oregon Experiment Station. Many hundreds of individual tests were made, involving a record of the germination of half a million wheat kernels of eighteen varieties, laboratory, greenhouse, and field. It is to be hoped that the results of this work will soon be published in full. In the meantime, certain important conclusions will be stated here.

Of the treatments experimented with, thirteen involved the use of copper sulfate (bluestone), thirty formaldehyde, three hot water, three calcium hypochlorite, and several mercuric chloride (corrosive sublimate). Of all those tested, the two following gave the best results in percentage of seedlings obtained and in total yield of wheat: (1) Dip (ten minutes) in a solution of one pound of copper sulfate to five gallons of water; drain fifteen minutes, and then dip five minutes in milk of lime, one pound of lime to ten gallons of water. (2) Three-minute dip in a solution of one pint of 37 percent commercial formaldehyde to three hundred twenty pints (forty gallons) of water; then cover for four hours.

Turkey wheat when treated by the first, or bluestone-lime method, gave an average increase of 18 percent of plants and 10 percent in yield of wheat over that obtained when the second or formaldehyde method, was used. Other varieties gave similar results.

Miss Rose's conclusions regarding the relation of threshing injury to treatment loss is in agreement with those of other investigators. For example, in one of her tests hand-threshed Turkey Red gave not only better germination, but also 59 percent greater yield of grain than machine-threshed seed. In Marquis there was a 16-percent gain.

Miss Rose found that uninjured wheat when treated by the bluestone-lime method and thoroughly dried, could be stored for two years with but little loss of germination power, and that the addition of salt to bluestone solutions somewhat increased the loss, the degree of injury being proportionate to the amount of salt used.

The general results of Miss Rose's experiments, as well as those of C. W. Hungerford assisted in part by J. T. Bregger, at Corvallis, confirm the general conclusions arrived at from the Moro experiments, although under the soil and climatic conditions of the Willamette Valley the extent of injury was not always as great as at Moro.

CONCLUSIONS DRAWN FROM EXPERIMENTS HEREIN DESCRIBED, AND THOSE OF OTHER INVESTIGATORS.

All investigators are practically agreed on the following points in regard to treatment of wheat with formaldehyde solutions:

(1) If the time of immersion and subsequent covering does not exceed four hours and the seed is sown soon after treatment, or while the seed is moist, in soil with enough moisture to cause immediate germination and uninterrupted growth, but little injury results.

(2) Sowing damp seed in dry soil is not advisable.

(3) Treated seed kept damp will not suffer further injury for several days, unless it heats or is attacked by molds. It is believed by some that the treated seed can be dried at comparatively high temperatures in atmosphere of the right humidity, and then stored dry for an indefinite time without greater loss than would have been sustained if it had been sown damp. The results of drying and storing formaldehyde-treated seed are, however, so dependent on atmospheric conditions and temperature and require such expert care that it is a hazardous process at best, and should be avoided when possible, unless the seed is washed in water immediately after the covering period.

Probably all persons who have used formaldehyde have observed a white, flocculent precipitate which forms in a bottle that has been standing for some time, and which readily dissolves when the liquid is warmed. This is known as paraformaldehyde, a very poisonous substance. Working in California, Hurd* found that the formation of this substance on the surface of formaldehyde-treated seed when it was dried after treatment was the cause of a larger part of the seed loss in dry storage. She proved by experiment that washing in water before drying prevented the formation of this injurious substance and removed the danger of after-treatment injury. It should be noted, however, that a certain amount of injury takes place during the treatment that no subsequent bath will obviate. Experiments at Corvallis and at Moro in the fall of 1921 show that a pure-water wash after formaldehyde was equally as effective in reducing seed injury as a wash in lime water.

It has been found that in farm practice too little attention is ordinarily paid to the strength of the bluestone solution used in treating seed. Soaking seed for five minutes in a solution of 1 lb. of bluestone to 5 to 10 gallons of water will ordinarily control bunt except in cases of bunt-infested soil. To lessen seed injury, an after-dip in lime water of the strength of 1 lb. of ordinary slaked lime to 10 gallons of water is always advisable.

The bluestone treatment is always to be preferred if the seed is to be stored for any length of time before sowing or if the seed is to be sown in dry ground.

For controlling bunt, a solution of formaldehyde stronger than 1 pint of commercial formaldehyde to 40 gallons of water is not necessary. One pint to 45 gallons with a five-minute soak has been found in farm practice to control stinking smut effectively where the soil is not contaminated with smut spores.

Treating seeds with bluestone or copper sulfate is a safer farm practice when the seed is sown in ground with insufficient moisture to start germination immediately, and maintain continuous growth.

The addition of common salt to a bluestone solution appears to increase its fungicidal properties but also causes slightly more seed injury. In most localities in Oregon, addition of salt is not necessary to control bunt.

During the past 30 years, chemists and other investigators have spent many days in the quest of a fungicide that would be efficient against the

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* Hurd, Dr. Annie May. Injury to seed wheat resulting from drying after disinfection with formaldehyde. Jour. Agr. Research, Vol. 20, No. 3, pp. 209-244, plates 36-41.

smuts and at the same time non-injurious to the seed. None has yet been found that meets both these conditions perfectly, unless the new method, now under trial, of treating with dry, powdered copper carbonate should prove to be the long-sought method. Darnell-Smith* after three years of trial in Australia reported the copper-carbonate treatment non-injurious to the seed and effectual against bunt. Professor W. W. Mackie of the University of California has made many trials and is favorably impressed with its results. Experimental work with this fungicide in Oregon is in progress and sufficient data are now available to prove that the copper-carbonate treatment causes little, if any, injury to the seed. In a field test near Corvallis seed treated by this method produced a stand fully equal to the untreated seed. Another season's results will be required to determine definitely whether this treatment will effectively control bunt under conditions prevailing in Oregon.

II. BUNT-RESISTANT WHEAT VARIETIES

Varieties of wheat vary greatly in their susceptibility to stinking smut. Some varieties are exceedingly resistant, while others are very susceptible to this disease. Of the commercial varieties of wheat now grown in Oregon, not one is sufficiently resistant to the disease to permit treatment of the seed to be dispensed with. If there can be developed high-yielding varieties sufficiently resistant to stinking smut so that untreated seed could be sown with an assurance of a comparatively smut-free crop, it would result in the saving of hundreds of thousands of dollars annually to the farmers of the State.

Of the wheat varieties grown commercially in Oregon, those of the Crimean group, such as Turkey, Kharkov, and Kanred, are the most smut-resistant, though none of these is sufficiently resistant to be safely sown without seed treatment.

In 1917 preliminary work in cooperation with the Office of Cereal Investigations of the United States Department of Agriculture was started at the Sherman County Branch Experiment Station and at Corvallis to determine the comparative smut resistance of wheat varieties. During the year 1917, Mr. F. J. Schneiderhan was in direct charge of the cereal breeding work at Moro.

In the fall of that year thirteen varieties of wheat were sown at Moro and Corvallis under the direction of Mr. C. W. Hungerford. At Corvallis the plantings were in plots of four one-rod rows replicated three times. Both soil and seed were artificially and heavily infested with spores of *T. tritici*. At Moro only one one-rod row was planted in infested soil and three one-rod rows with the seed only infested.

The results are given in Table XV.

In the fall of 1918 this work was elaborated on a rather large scale. All of the commercial wheats of the United States, assembled by Messrs. Ball and Clark and grown in the classification nursery at Moro, were sown in rod rows with heavily smutted seed. In this trial were 455 varieties or pure-line selections. These varieties were also all sown with smutted seed in the autumn of 1919. Two years' data, therefore, are available on the comparative smut resistance of all the commercial wheat varieties of the

* Darnell-Smith. A dry method of treating seed wheat for bunt. Agr. Gaz. N. S. Wales V. 30, part 10, pp. 685-692.

TABLE XV. RESULTS OF VARIETY TESTS FOR BUNT RESISTANCE IN PERCENTAGE OF BUNTED HEADS FOR THE SEASON OF 1917-18 AT CORVALLIS AND MORO, OREGON.

Variety	Corvallis	Moro		Average
	Soil and seed infested	Soil and seed infested	Seed only infested	
	%	%	%	%
Eaton	79	74	79	77.3
Foisy	84	75	70	76.3
Fortyfold	71	88.5	70	76.5
Golden Cross	62	76	64	67.3
Jones Fife	71	87	61	73.0
Kinney	72	84	80	78.7
Little Club	81	80	72	77.7
Queen Wilhilmina	67	66	61	64.7
Red Russian	37	72	68	59.0
Titanic	6.3	6	1.6	2.8
Turkey, C. I. 1558	47	18	17	27.3
Hybrid 128	62	74	54	63.3
White Winter	79.5	83	74	78.8

United States. There were also sown in the fall of 1918, 134 two-rod rows of pure-line selections from Crimean wheats that had been previously made by Mr. Schneiderhan at the Branch Station at Moro and were being tested for yield. Many of these selections had been grown for several years without seed treatment and contained no smut. It was thought, therefore, that some of them might prove to be more resistant to this disease than the common Crimean varieties.

In the spring of 1919, the commercial wheat varieties of Australia, comprising 85 varieties, and the commercial wheats of India, comprising 120 varieties, were sown in two-rod rows with artificially smutted seed. These wheats had previously been obtained by the United States Department of Agriculture from these countries for experimental purposes.

In Table XVI are listed most of the common wheat varieties grown in the Northwest and other commercial wheat varieties of the United States which contained the least smut in the 1919 and 1920 crops. The percentage of smut in each variety is based on the number of smutted heads in comparison with the total number of heads in a rod row. A complete list of the varieties tested for smut is not included in this bulletin.

TABLE XVI. LIST OF WINTER WHEAT VARIETIES GROWN AT MORO, OREGON, IN 1919 AND 1920, FROM ARTIFICIALLY INFESTED SEED, SHOWING PERCENTAGE OF SMUT INFECTION IN RESULTING PLANTS

Variety	C. I. No.	Percentage of smutted HEADS ~~plants~~ in		
		1919	1920	Average
		%	%	%
Martin (Martin Amber)	4463	00	00	00
Martin (Martin Amber)	4636	90	77	83
Prohibition	4068	96	97	96
White Winter	4684	34	81	57
White Winter	5219	75	93	84
White Winter	5224	39	94	66
Challenge (Webb Challenge White)	4683	37	75	56
Challenge (Webb Challenge White)	4684-B	15	91	53
Challenge (Webb Challenge White)	5227-B	87	87	87
Eaton	4362	42	84	63
Eaton	4682	96	82	89
Eaton	5219-B	24	90	57
Defiance	4347	97	83	90
Defiance	4354	71	①	....
Defiance	4764	65	①	....
Rink	5866	96	91	93
Rink	5867	96	68	82
Rink	5868	58	91	74
Gypsum (Colorado Special)	4761	71	①	....
Gypsum (Colorado Special)	4762	78	91	84
Gypsum (Colorado Special)	4928	15	90	52
Pacific Bluestem	4067	28	94	61
Pacific Bluestem	4606	51	65	58
Pacific Bluestem (White Australian)	3019	52	46	49
White Track	5230	94	81	87
White Track	5231	80	65	72
White Track	5267	85	92	88
Dicklow	3663	75	①	....
Dicklow	5285	99	①	....
Dicklow	5898	76	①	....
Surprise (California Gem)	2986	85	①	....
Surprise (California Gem)	4248	76	①	....
Surprise (White Russian)	5277	71	①	....
Bobs	4990	69	50	59
White Fife	4412	53	34	43
White Fife	4955	35	50	42
Regenerated Defiance	3703	50	①	....
Regenerated Defiance	4763	50	①	....
Regenerated Defiance	5265	53	81	67
Lofthouse	3275	78	76	77
Lofthouse	5875	95	84	89
Red Russian	4509	83	90	86
Red Russian	4681	83	80	81
Kinney	5189	95	94	94
Kinney	5192	55	90	72
Kinney	5195	80	81	80
Huston	5208	60	70	65
Huston	5209	71	73	72
Marquis	3641	32	40	36
Marquis	5954	75	45	60
Marquis	5294	67	34	50
Kofod	2997	60	75	67
Kofod	4337	0.3	25	12
Kofod	4339	00	7.7	3
White Odessa	4480	78	66	72
White Odessa	4651	1	00	0.5
White Odessa	4655	4	0.7	2
Foisy	5242	83	94	88
Foisy	5246	71	80	79
Foisy (Oregon Goldenchaff)	5283	82	60	75
Arcadian (Early Arcadian)	3390	97	70	83

①Winter killed.

TABLE XVI.—(Continued)

Variety	C. I. No.	Percentage of smutted ~~plants~~ HEADS in 1919	1920	Average
		%	%	%
Arcadian (Early Arcadian)	4220	85	75	80
Arcadian (Early Arcadian)	5871	88	70	79
Goldcoin (Fortyfold)	2996	87	67	77
Goldcoin (Fortyfold)	4230	80	60	70
Goldcoin (Fortyfold)	4500	39	72	55
Allen (Red Allen)	5407	11	①	....
Federation	4609	30	①	....
Hard Federation	4980	62	50	56
Odessa	3003	93	94	93
Odessa	3274	51	85	68
Odessa	4475	56	57	56
Jumbuck	4608	8	76	42
Triplet	5408	91	80	85
Jones Fife	4468	77	51	64
Jones Fife	5236	78	66	72
Jones Fife (Crail Fife)	4162	84	91	87
Jones Fife (Super)	5544	75	86	80
Galgalos	2398	49	56	52
Galgalos	4467	24	60	42
Sonora	3036	56	①	....
Sonora	4293	98	①	....
Sonora	4501	52	①	....
Baart (Early Baart)	1697	32	100	66
Baart (Early Baart)	4206	18	73	45
Saumur	2346	23	45	34
Talimka	2945	27	45	38
Hussar (Red Hussar)	4843	00	00	00
Kharkov	1442	5	.06	2
Turkey	1558	9	.08	4
Beloglina	1543	25	30	27
Beloglina	1667	13	20	16
Beloglina	2239	90	60	75
Kanred	5146	00	11	5
Prelude	4323	72	①	....
Hybrid 60	5024	99	92	95
Hybrid 128	4229	82	93	87
Hybrid 128	4257	29	94	61
Hybrid 128	4512	88	95	91
Little Club	4066	50	90	70
Little Club	4225	73	100	86
Little Club	5897	78	87	82
Big Club	4209	63	96	79
Big Club	4257	44	50	47
Big Club (Salt Lake Club)	3018	50	①	....
Hybrid 63	4157	95	95	95
Hybrid 63	4252	78	100	89
Hybrid 63	4510	90	95	92
Hybrid 143	4160	95	100	97
Hybrid 143	4513	87	96	91
Hybrid 143	5255	94	90	92
Washington No. 3	4239	3	16	9
Washington No. 3	4669	13	20	16
Hybrid 108	5025	82	66	74
Hybrid 123	4511	91	60	75
Jenkin	5177	46	①	....
Jenkin	5261	85	①	....
Jenkin	5903	51	①	....
Redchaff	4241	60	①	....
Redchaff	4243	58	①	....
Redchaff	4250	41	①	....
Bluechaff	5178	68	①	....
Bluechaff	5256	23	99	61
Bluechaff	5257	42	96	69
Dale (Dale Gloria)	4155	51	①	....
Dale (Dale Gloria)	4255	54	①	....
Dale (Dale Gloria)	5902-A	68	①	....
Coppei	3088	75	60	67
Coppei	4238	73	50	61
Mayview	5874	74	①	....

① Winter killed.

The Pure-Line Crimean Wheats. Of the pure-line Crimean wheats, the varieties listed in Table XVII were the ones that showed least smut infection. The percentage of smut is based on the number of smutted heads compared with the total number of heads in a two-rod row. The total number of heads in each row varied from 420 to 1175.

TABLE XVII. PURE-LINE SELECTIONS FROM CRIMEAN WHEATS GROWN AT MORO, OREGON, IN 1919 SHOWING PERCENTAGE OF SMUT IN PLANTS FROM ARTIFICIALLY INFESTED SEED.

Original name	C. I. No. and selection designation	Percent smut
Turkey	P-704 ①	7.0
Kharkov	1442-B	3.2
	1532	2.3
Turkey	1558-A	2.8
Turkey	1558-3-09	9.6
Weissenberg	1563-2	5.2
Polish	1565-1	2.8
Turkey	1571-C	6.5
Girgeh	1580-11	7.5
Servian	1728-1-4-1-10	5.9
Diminum	2191-1	5.5
	2576-A	3.6
Rietti	2578-1	0.54
Mediterranean	2903-5	2.3
Molakof	2908-A	1.8
Turkey	3055-A	1.0
	44 30	3.6

① Pedigree number of the Botany department of the Kansas Agricultural Experiment Station.

Australian and Indian Wheat Varieties. Of the 85 Australian wheat varieties, the following contained the least smut:

Variety	C. I. number	Percent smut
Nardoo	4985	10
Cowra No. 16	4738	14
Florence	4170	16

Of the Indian wheats there was not one of the 120 varieties that showed any resistance to this disease.

The outstanding feature of the 1919 harvest was the discovery of the immune or highly resistant character of Red Hussar, C. I. 4843, Martin Amber, C. I. 4463 and White Odessa, C. I. 4651 and 4655. The first two have never yet shown a trace of bunt, while the two White Odessa strains have averaged less than 1 percent of bunted heads. Red Hussar is a hard, red-bearded wheat, while Martin Amber and the White Odessas are soft, white, and beardless.

Results for 1919-20. In the fall of 1919, the classification nursery list was again planted at Moro, and in addition the most promising bunt-resistant varieties were planted at Corvallis, Moro, Hermiston, and Union. Several strains of Florence x Turkey and Hybrid 128 x Turkey, produced by Dr. E. F. Gaines of the Washington Agricultural Experiment Station at Pullman, were sent to us by him. Some of these give promise of being valuable resistant wheats.

The results of this year's work are summarized in Table XVIII.

TABLE XVIII. PERCENTAGE OF SMUT IN WINTER WHEAT VARIETIES GROWN AT MORO, CORVALLIS, HERMISTON, AND UNION, OREGON, IN 1920, FROM ARTIFICIALLY INFESTED SEED

Variety	C. I. No.	Percentage of smutted heads at				
		Corvallis	Moro	Hermiston	Union	Average
		%	%	%	%	%
Hybrid 143	4513	70.8	68.0	60.3	15.4	53.6
Turkey	-------	20.5	14.6	19.6	6.6	15.3
"Banner Berkeley'	-------	1.8	0.6	0.0	0.0	0.6
Medeah	-------	0.0	-------	-------	-------	0.0
Red Hussar	4843	0.0	0.0	0.0	0.0	0.0
Red Allen	5407	30.6	-------	-------	-------	30.6
Alaska x Jones Fife	6682	10.6	2.8	0.0	1.3	3.7
Kharkov	1442	24.5	4.7	0.0	2.7	8.0
Kharkov	1442–12	26.6	18.9	4.5	2.5	13.1
Turkey (Wn. No. 326)	6175	28.0	2.7	1.4	1.2	8.3
Turkey	1558	14.8	10.6	0.0	1.8	6.8
Kofod	4337	7.2	24.2	-------	-------	15.7
Kofod	4339	6.4	7.7	-------	-------	7.05
Washington No. 3	4669	6.7	1.5	-------	0.0	2.7
Washington No. 3	4239	74.5	16.2	-------	4.8	31.8
Florence	-------	4.9	2.6	-------	0.0	2.5
White Odessa	4651	0.0	0.0	0.0	0.0	0.0
White Odessa	4655	2.1	0.7	-------	0.0	0.9
Martin	4463	-------	0.0	-------	-------	0.0
Crimean selections	2191–1	0.0	0.6	0.0	0.2	0.2
	1558–A	0.0	1.8	2.4	0.0	1.05
	1558–B	0.9	0.0	0.0	0.3	0.3
	1558–11	20.5	1.5	0.0	0.8	5.7
	1558–3–09	20.3	1.4	0.0	0.3	5.5
	4430	0.6	0.5	0.0	0.0	0.3
	2576–A	0.4	0.0	0.0	0.0	0.1
	1442–15–09	23.2	2.7	0.0	0.0	6.5
	2578–1	0.5	0.0	0.0	1.3	0.45
	2908-A	11.2	0.8	0.0	0.0	3.0
	3055-A	0.0	0.0	0.0	0.0	0.0
	1728–1–4–1–10	12.8	1.1	2.6	0.8	4.3
	1563–2	7.1	2.0	0.0	0.0	2.3
	1571-C	0.6	1.0	1.6	0.0	0.8
	2903–5	0.0	0.0	0.0	1.0	0.25
	1565–1	0.8	2.3	3.6	0.0	1.7
	1532	0.2	0.4	3.3	0.0	1.0
P-704	-------	31.5	3.1	2.4	1.0	9.5
Turk. x Hyb. 128 (G 176)	-------	23.0	11.2	16.0	5.1	13.8
Turk. x Hyb. 128 (G 238)	-------	46.1	8.2	11.0	2.0	16.8
Turk. x Hyb. 128 (G 242)	-------	22.6	13.7	17.9	5.8	15.0
Turk. x Hyb. 128 (G 247)	-------	44.6	10.6	6.0	2.9	16.0
Turk. x Hyb. 128 (G 308)	-------	33.9	10.6	13.8	3.5	15.45
Turk. x Hyb. 128 (G 311)	-------	50.2	15.6	22.7	9.8	24.6
Turk. x Florence (G 314)	-------	2.3	1.6	1.9	0.8	1.65
Turk. x Florence (G 316)	-------	2.4	0.0	0.0	0.3	0.7
Turk. x Florence (G 324)	-------	1.1	0.0	0.7	0.0	0.45
Turk. x Florence (G 326)	-------	0.0	trace	0.0	0.0	0.0
Turk. x Florence (G 330)	-------	0.5	0.0	0.0	0.0	0.1
Turk. x Florence (G 332)	-------	0.7	1.1	0.9	0.0	0.7
Turk. x Florence (G 334)	-------	2.8	1.0	trace	0.0	0.95
Tur. x Fl. (G 352) (brded)	-------	3.6	0.5	3.5	0.0	1.9
Tur. x Fl. (G 352) (brdl's)	-------	4.9	1.3	3.3	0.0	2.4

Results in 1921. In the autumn of 1920 there were sown at Moro and at Corvallis with artificially smutted seed in two-rod rows those varieties which had previously showed some resistance to stinking smut and a few standard varieties for comparison. There were also included three varieties, Blackhull, Alberta Red, C. I. No. 5971, and bulk seed of Red Hussar

obtained from the Illinois Agricultural Experiment Station. The percentage of smut obtained in the 1921 crop of each variety grown at Moro and at Corvallis is given in Table XIX, with the average percentage for both places.

TABLE XIX. PERCENTAGE OF SMUT IN WINTER WHEAT VARIETIES GROWN AT MORO, AND CORVALLIS, OREGON, IN 1921.

Variety	C. I. No.	Percentage of smutted heads at Moro	Corvallis	Average
		%	%	%
Hybrid 143	....	43.0	82.0	62.0
Banner Berkeley	....	0.6	0.5	0.5
Martin	....	0.0	0.0	0.0
Red Hussar	....	0.0	0.0	0.0
Alaska x Jones Fife	....	2.5	13.0	7.7
Turkey (Washington No. 326)	....	3.1	18.0	10.5
Kofod	4337	2.4	29.0	16.0
Kofod	4339	1.6	13.0	7.3
Washington No. 3	4669	6.0	10.0	8.0
Washington No. 3	4239	10.0	58.0	34.0
Florence	....	2.2	11.0	6.6
White Odessa	4651	0.2	0.0	0.1
White Odessa	4655	0.0	0.0	0.0
Kanred	5146	6.0	11.0	8.0
Turkey (889)	....	4.0	8.7	6.3
Crimean selections	1558-A	3.2	0.4	1.8
	1558-B	1.1	0.9	1.0
	2191-1	1.5	0.0	0.7
	4430	0.2	0.0	0.1
	2576-A	2.0	0.8	1.4
	1532	5.9	2.8	4.3
	2578-1	1.6	1.4	1.5
	2908-A	0.7	5.8	3.2
	3055-A	0.3	0.3	0.3
	1728-1-4-1-10	3.0	5.2	4.1
	1563-2	0.3	1.4	0.8
	1571-C	1.0	0.0	0.5
	2903-5	0.6	0.0	0.3
	1565-1	2.8	5.6	4.2
Turkey x Hyb. 128 (G 176)	....	4.3	29.0	16.0
Turkey x Hybrid 128 (G 238)	....	4.2	42.0	23.0
Turkey x Hybrid 128 (G 242)	....	2.3	60.0	31.0
Turkey x Hybrid 128 (G 247)	....	6.0	39.0	22.0
Washington No. 13001	....	10.0	35.0	22.0
Hybrid 128	....	70.0	55.0	62.0
Turkey x Florence (G 314 Red)	....	0.0	0.0	0.0
Turk. x Florence (G 314 White)	....	0.3	0.0	0.1
Turkey x Florence (G 316)	....	0.1	0.0	.05
Turkey x Florence (G 324)	....	0.0	0.8	0.4
Turkey x Florence (G 326 Red)	....	0.2	0.0	0.1
Turk. x Florence (G 326 White)	....	0.0	0.0	0.0
Turkey x Florence (G 330)	....	0.2	0.82	0.5
Turkey x Florence (G 332)	....	0.0	4.82	2.4
Turkey x Florence (G 334)	....	0.0	1.84	0.9
Blackhull	....	44.0	....	.....
Alberta Red	5971	12.0		.....
Red Hussar (Bulk seed)①	....	10.0		.....

① Seed from Illinois Agricultural Experiment Station.

Yields of Smut-Resistant Varieties. Comparative yields of the smut-resistant varieties were obtained in 1920 and 1921 in two-rod nursery rows replicated from three to five times. The annual and average yields are reported in Table XX, together with the yields of a pure line of Kharkov

winter wheat, C. I. 1442-12. These wheats will be further tested in larger plots to determine which are the highest yielding varieties.

TABLE XX. ANNUAL AND AVERAGE ACRE YIELDS, IN BUSHELS, OF SMUT-RESISTANT WHEAT VARIETIES GROWN IN NURSERY ROWS AT MORO, OREGON, IN 1920 AND 1921

Variety	C. I. No.	Acre yield		
		1920	1921	Average
		bu.	bu.	bu.
Crimean selection	1532	21.7	33.5	27.6
Crimean selection	1558-A	32.5	30.2	31.3
Crimean selection	1558-B	23.3	29.7	26.5
Crimean selection	1565	14.6	20.9	17.7
Crimean selection	2191–1	20.2	22.6	22.4
Crimean selection	2576-A	17.1	29.6	23.3
Crimean selection	2578–1	17.1	30.7	23.9
Crimean selection	2903–5	21.3	31.4	26.3
Crimean selection	2908–A	18.7	26.6	22.6
Crimean selection	3055-A	18.2	32.0	25.1
Crimean selection	4430	28.7	33.1	30.9
Crimean selection	1563–2	12.0	27.6	19.8
Crimean selection	1728–1–4	14.7	26.8	20.2
Crimean selection	1571-C	15.6	34.5	25.0
Crimean selection	4337	8.5	20.3	14.4
White Odessa	4651	9.7	22.1	15.9
White Odessa	4655	11.7	35.1	23.4
Martin	4463	21.0	23.5	22.2
Banner Berkeley	....	13.6	26.5	20.0
Red Hussar	4843	17.0	25.2	21.1
Kharkov	1442–12	21.3	29.4	25.3
Turkey x Florence (Wash. No. 326)				
Turkey x Florence selection G314	....	19.8	21.8	20.8
Turkey x Florence selection G316	....	16.9	28.7	22.8
Turkey x Florence selection G324	....	19.1	20.2	19.6
Turkey x Florence selection G326	....	24.6	30.9	27.7
Turkey x Florence selection G330	....	19.5	28.2	23.8
Turkey x Florence selection G332	....	18.9	34.2	26.5
Turkey x Florence selection G334	....	18.8	26.5	22.6

The following is a brief description of the varieties which, from the two years' nursery trial, appear to be the most promising from the standpoint of yield:

Turkey C. I. 1558 A. A selection made from Turkey, C. I. 1558, by Dr. C. R. Ball in 1915. The variety is a typical Turkey wheat. At Corvallis it comes nearest of all the hard red wheats to being free from yellowberry.

Turkey C. I. 1558 B. This variety differs from C. I. 1558 A in that it has a stiffer straw and the heads when ripe stand more erect than in the Turkey variety.

Crimean C. I. 2903-5. A selection from the Mediterranean variety made at Amarillo, Texas. The kernels and plant characters are similar to those of Turkey wheat.

Turkey C. I. 3055. This is a selection from Turkey wheat made at the Highmore Substation at Highmore, South Dakota. The spikes of this variety are somewhat longer and more lax than those of the Turkey variety. The heads are pendant when ripe and do not shatter readily.

Crimean C. I. 4430. This is a pure-line selection from Crimean wheat made by J. A. Clark from a field plot at Moccasin, Montana, in 1915. The heads are large and erect, and are somewhat inclined to shatter. The kernels appear to be similar to those of Turkey wheat.

Turkey C. I. 1571 C. Turkey C. I. 1571 has been one of the highest yielding Crimean wheats tested at the Sherman County Branch Experiment Station. This strain appears identical with Turkey wheat but is considerably more smut-resistant than Turkey C. I. 1571, from which it was selected.

White Odessa C. I. 4655. This is a beardless, red-chaff wheat with white kernels. It has a long slender spike and matures rather late. It is weak-strawed when grown at Corvallis.

Martin Amber C. I. 4463. This is one of the latest maturing wheats of the smut-resistant group. It is a beardless wheat with white chaff and white kernels. It has always been smut-free at Moro and Corvallis and elsewhere so far as is known.

Red Hussar C. I. 4843. The original seed of this variety was obtained from the Illinois Agricultural Experiment Station. It is a pure-line selection that appears to be immune to stinking smut. Bulk seed of the same variety received in the fall of 1920 from the Illinois Experiment Station was not exceptionally smut-resistant. The variety is a bearded wheat with a rather long head. The kernels are large, hard, and red. The variety shatters quite badly at Moro. It has excellent baking qualities.

Turkey x Florence. These are hybrids made by Dr. E. F. Gaines of the Washington Experiment Station. The selections that have been grown in Oregon are all beardless with long, slender heads and white glumes, resembling Florence. They were all supposed to be red but two white strains have been selected from them. The selections are exceedingly smut-resistant, all of them possessing much more resistance than either of the parents, which, in the United States at least, prior to 1917 were the most resistant varieties known. The fact that highly resistant strains have resulted from the crossing of two varieties of only moderate resistance is of the highest significance genetically and promises greater achievements for the future. This phase has been treated by Dr. Gaines in the Journal of the American Society of Agronomy for April, 1920.

As presented in foregoing data, the tests in Oregon of over 800 varieties and strains have resulted in the finding of eighteen or more varieties and selections which show marked resistance or complete immunity to bunt. These include types of hard and soft white, and hard and soft red wheats, some of which have excellent milling and baking qualities. These facts promise much for the eventual elimination of the bunt nuisance from the wheat industry in all parts of the State.

SUMMARY

Seed Treatment Experiments

Bunt or stinking smut is one of the most serious diseases affecting wheat in Oregon.

This disease is caused by bunt spores adhering to the seed after threshing, or by wind-borne spores being deposited on summer-fallowed soil. These spores germinate and send out infection threads, which enter the underground portion of the young wheat plant, grow with it, and finally cause smutted wheat.

Seed-borne spores are the most common method of infection where seed is not treated. Investigations in the summer of 1918 indicate that

wind-borne spores cause the principal part of the infection in Eastern Oregon, notably in Umatilla county.

Of the two species of organisms causing bunt *(Tilletia tritici* and *Tilletia levis)*, both are found in the Willamette Valley, but only one, *Tilletia tritici*, is found in Eastern Oregon.

Experiments carried on at several points in Eastern and Western Oregon indicate that both species of bunt are of about equal virulence.

Observations made in Oregon as early as 1912 indicated that seed treatment for bunt frequently was responsible for injury to seed germination and reduction of stands of winter wheat. Since 1912, elaborate experiments have been conducted in cooperation with the Office of Cereal Investigations of the United States Department of Agriculture to determine the effect of seed treatment on germination of seed and on the control of stinking smut. The results of these experiments show that:

(1) Solutions of formaldehyde and bluestone of sufficient strength to kill the smut may, under certain conditions, destroy or delay germination or seriously reduce or impair the vigor of the young growing plants.

(2) Injury to formaldehyde-treated seed is considerably lessened by washing the seed in clear water after treatment.

(3) Injury to seed by the bluestone treatment is also materially lessened by washing or rinsing the seed in a solution of lime water.

(4) In the Moro tests, formaldehyde solutions of 1 pint of commercial formaldehyde to 45 gallons of water and bluestone solutions of one pound to ten gallons of water were equally effective in controlling bunt.

(5) Seed treated with formaldehyde should be sown as soon as possible after treatment, or while seed is damp, and only in moist soil.

(6) Either storing formaldehyde-treated seed or sowing in dry ground is a dangerous farm practice.

(7) The bluestone treatment is to be preferred if the seed is to be stored for any length of time or if the seed is to be sown in dry soil.

(8) The injury caused to seed by the formaldehyde and bluestone treatments usually depends upon the extent of injury done to the seed by the threshing machine.

(9) Elaborate experiments reported in this bulletin show that hand-threshed seed is only slightly injured by the formaldehyde and bluestone treatments.

(10) The treating of seed with dry copper carbonate, which has been found to control bunt in Australia and in California, does not injure the seed. Experiments are in progress to determine whether this treatment will effectively control bunt in Oregon.

Bunt-Resistant Wheat Varieties

Experiments to determine the susceptibility of different wheat varieties to stinking smut were begun at Moro in 1917.

All the commercial wheat varieties of the United States, Australia, and India, as well as hundreds of pure-line selections of wheat varieties, were tested for smut at Moro for the two years, 1919 and 1920. The comparative smut resistance for the two years of the common wheat varieties grown in the Northwest is shown in Table X.

A few pure-line selections of wheat varieties were discovered that are totally immune to both species of stinking smut. Nearly twenty varieties of wheats were found that were so highly resistant to this disease that they can be safely sown without treatment for bunt.

The discovery of these wheat varieties is likely to prove of much economic importance to the wheat-growing industry of Oregon and will probably mean the eventual elimination of the bunt nuisance from the State. This would mean an annual saving to farmers of many thousands of dollars.

In these varieties and pure-line selections of wheat are many different types ranging from soft white to hard red. All of them are being increased and tested for yield in several localities in Oregon.

A brief description of some of the new bunt-immune and bunt-resistant varieties is given on pages 37 to 42.